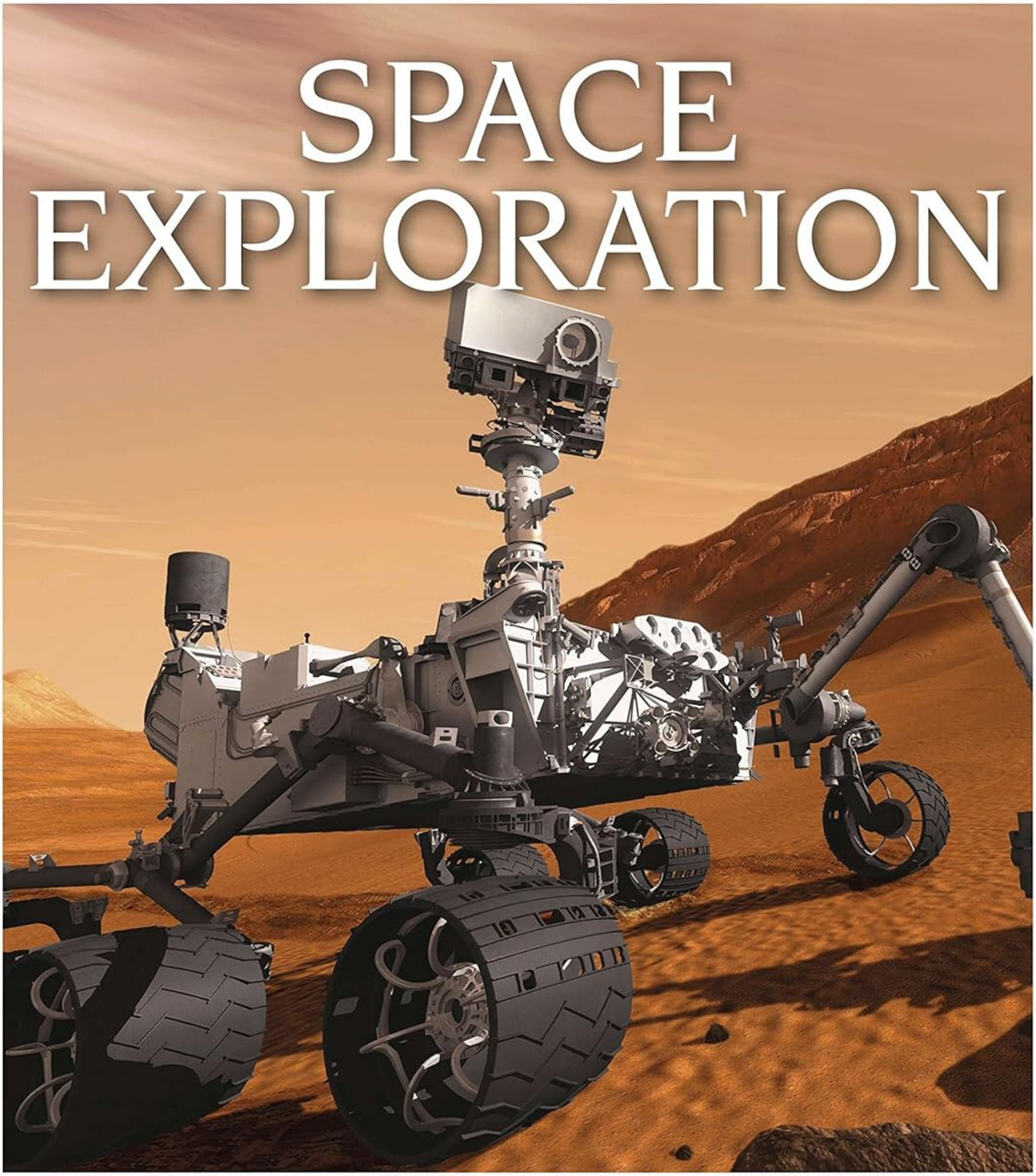
DK EYEWITNESS

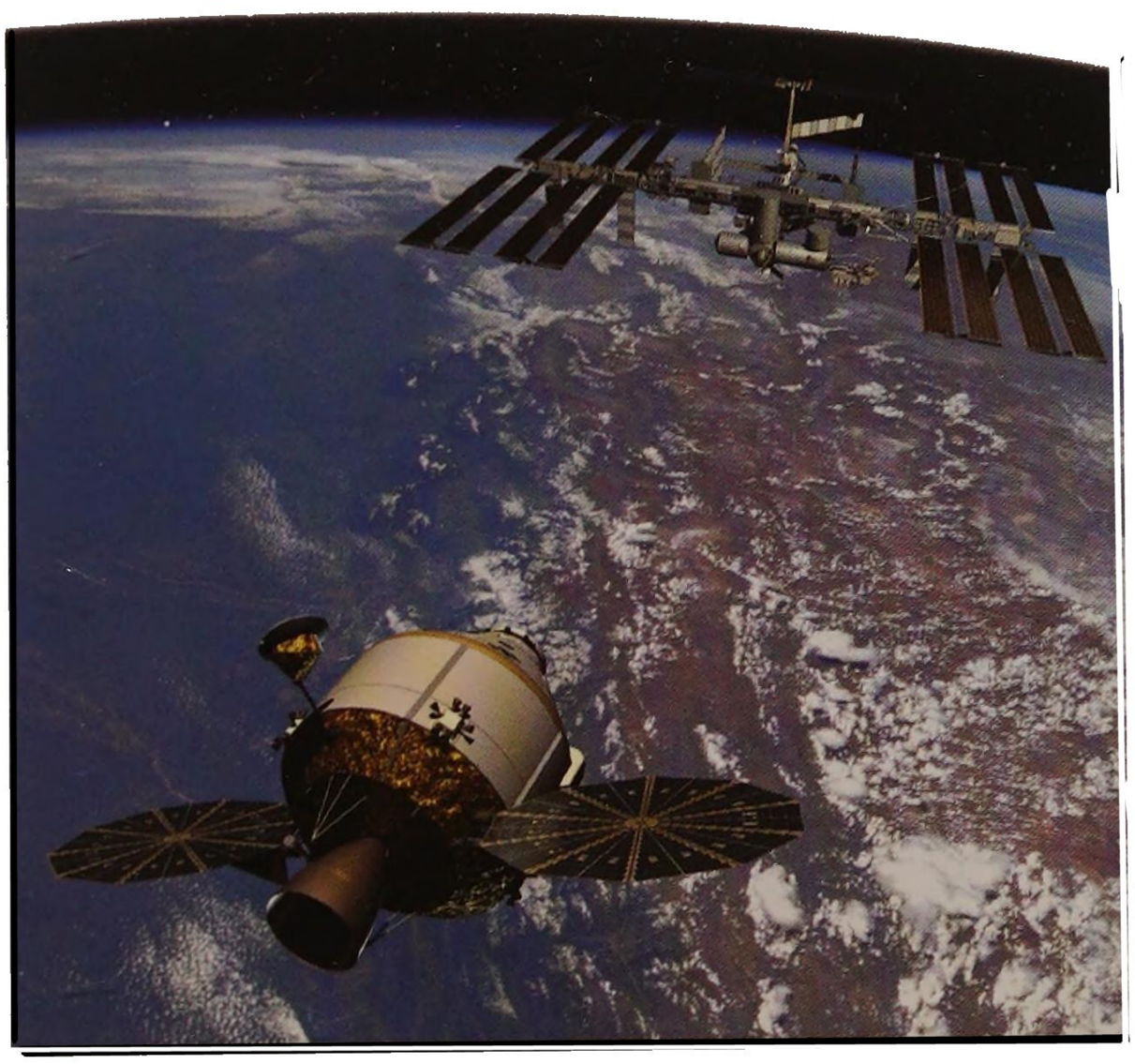
SPACE EXPLORATION

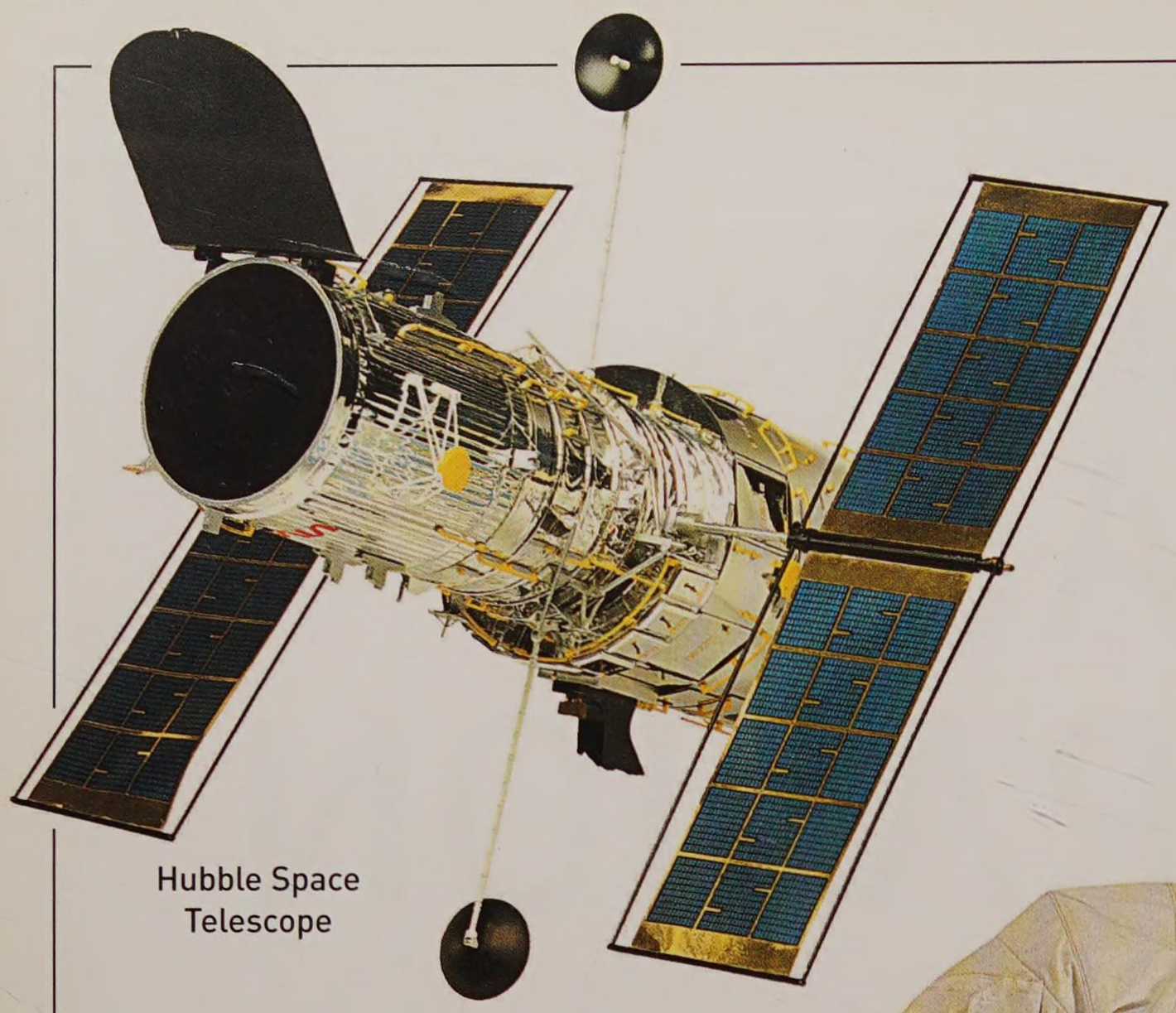


Blast into space and hitch a ride on the earliest rockets and the latest probes

EYEWITNESS

SPACE EXPLORATION





Hubble Space Telescope

Potential damage of space dust on shuttle window

Satellite material

Toys taken into space

Japanese space agency (NASDA) lapel pin

Patch worn by first Mongolian in space

Giotto space probe

Residue from solid rocket boosters

Spacesuit designed for use on the Moon

Rock collected on the Moon

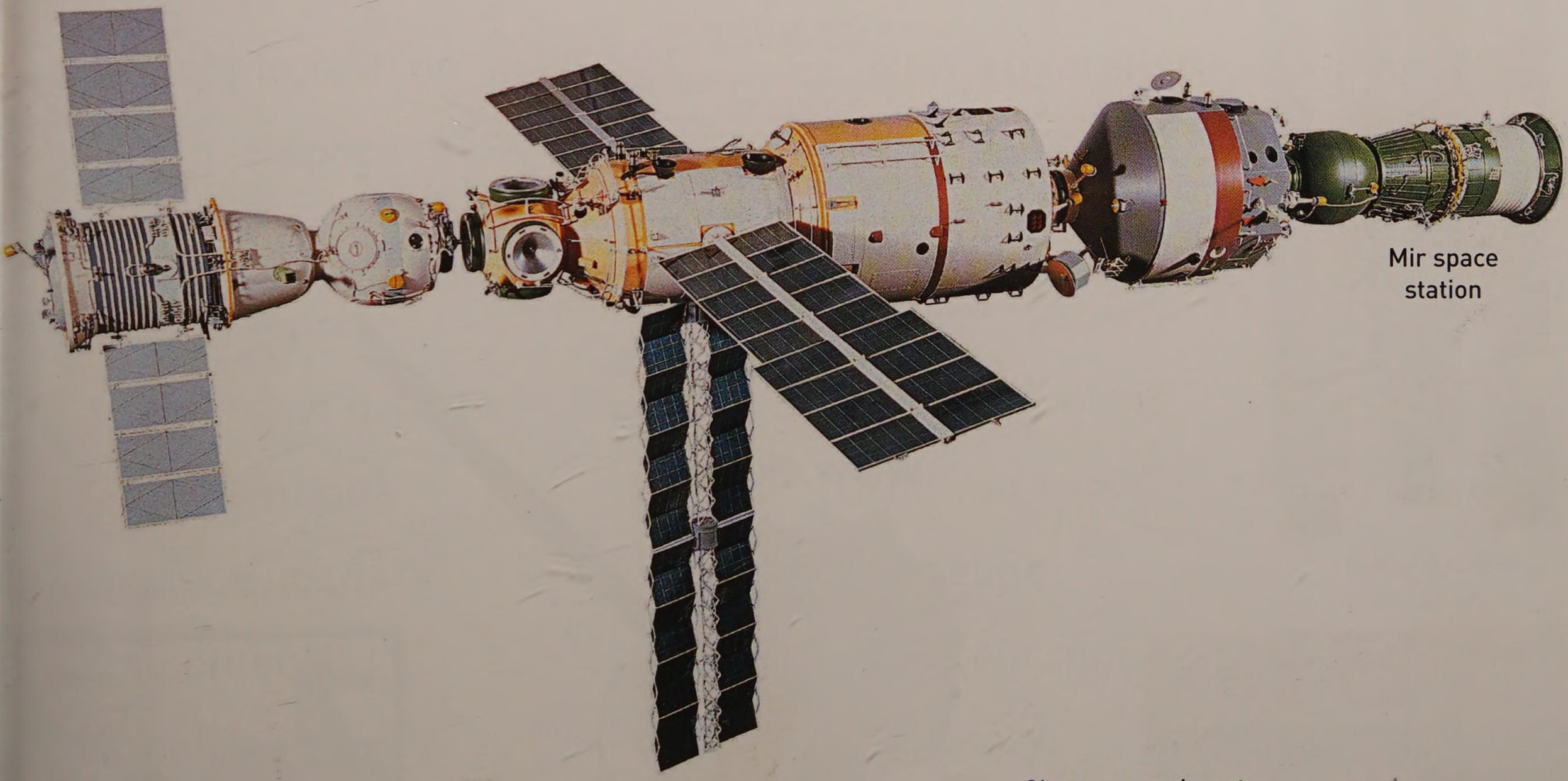
Vase commemorating Polish and Soviet space flight

EYEWITNESS SPACE EXPLORATION

In-flight space clothes worn on Mir

Written by
CAROLE STOTT

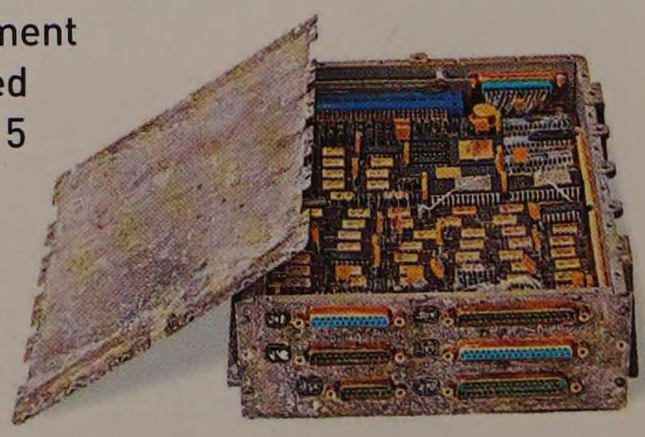
Photographed by
STEVE GORTON

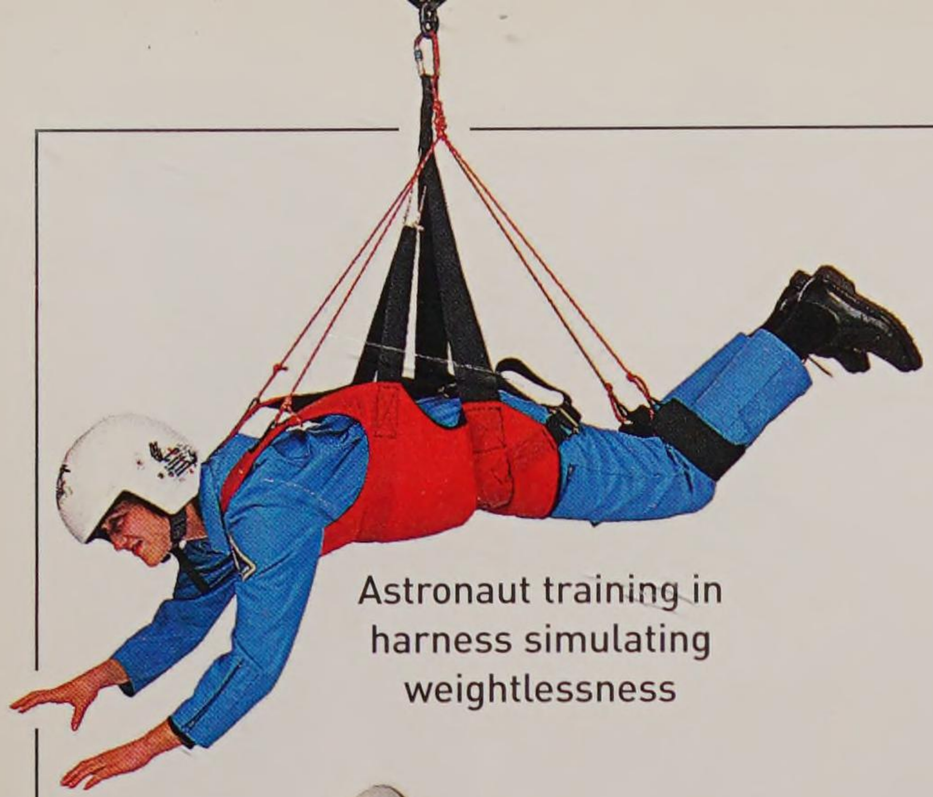


Mir space station

Pin of Soviet shuttle, Buran

Cluster experiment box recovered from Ariane 5





Astronaut training in harness simulating weightlessness

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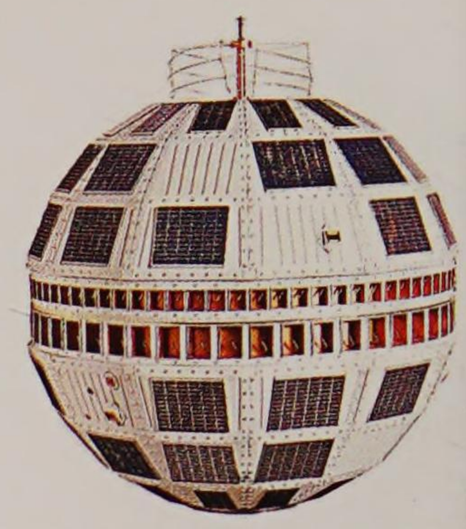
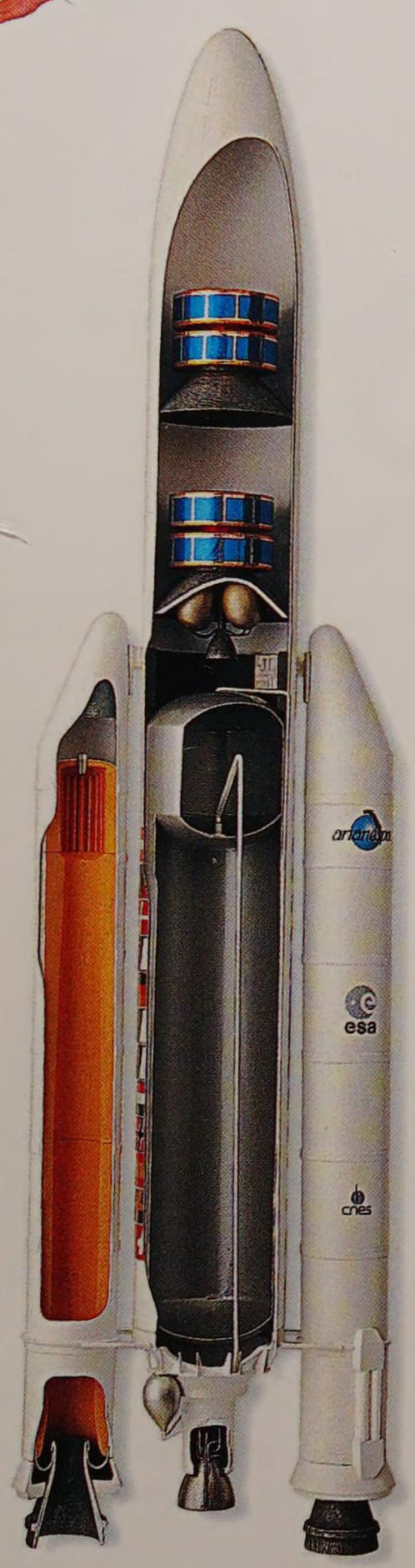


Telstar television satellite

Space food—dehydrated fruit



Ariane 5 rocket

German Democratic Republic patch

Progress craft carries supplies to the International Space Station

Indian space patch

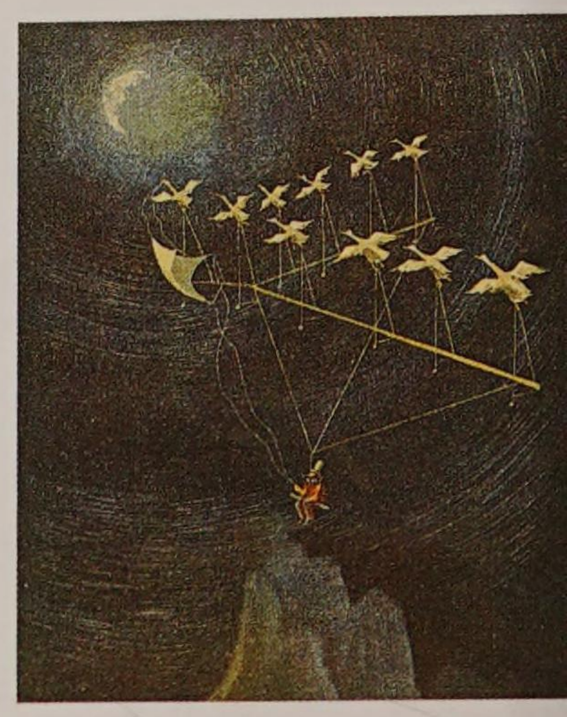
Contents

Astronaut's footprint on the lunar surface

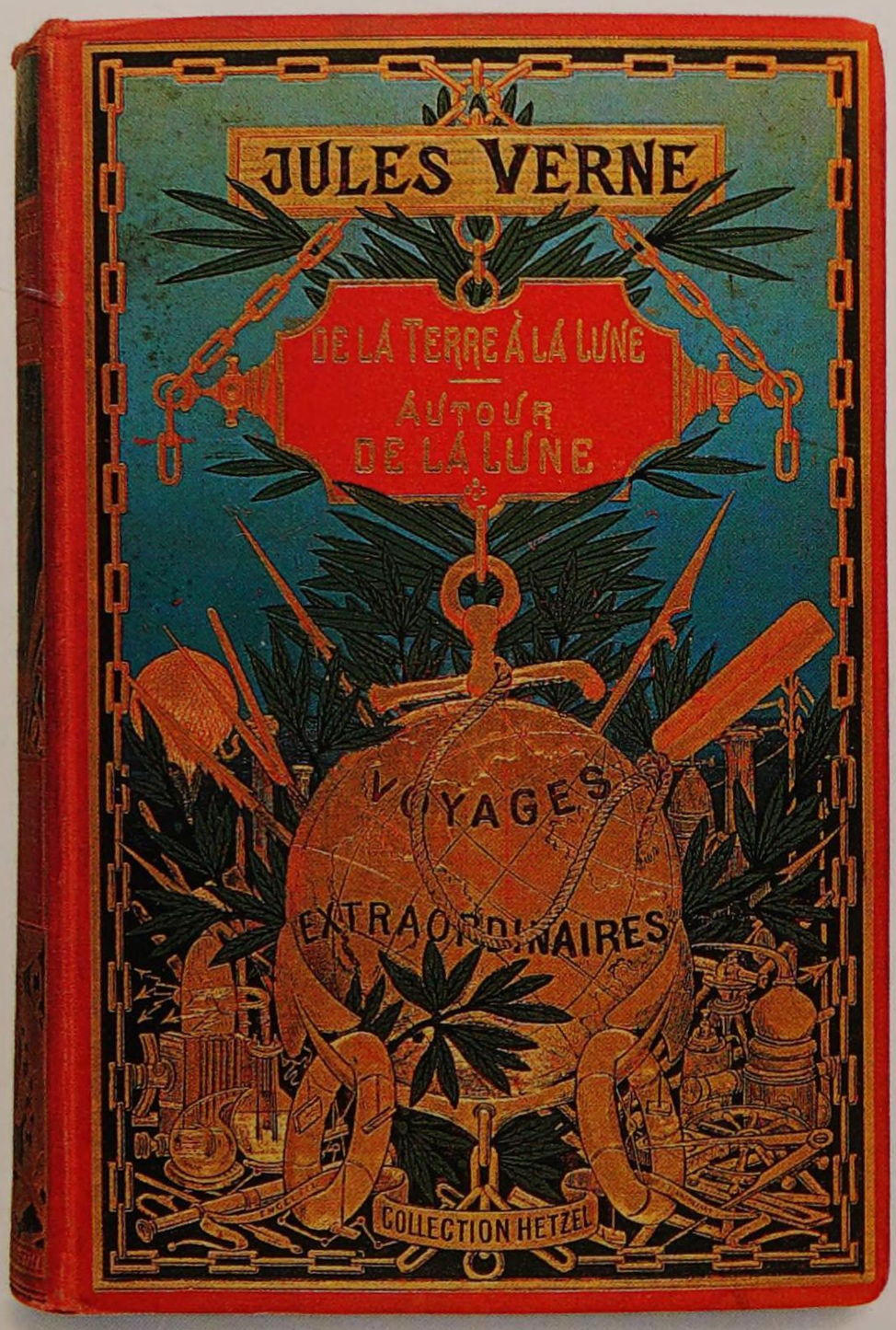
Space dreams

Humans have always looked into the sky and wondered about what lies beyond Earth. Many dream of journeying into space, exploring the Moon, or landing on Mars. Space travel became a reality in the 20th century when rockets were developed to blast away from Earth. In 1961, the first person reached space. Today, thousands of spacecraft and hundreds of space travelers have been launched into space.

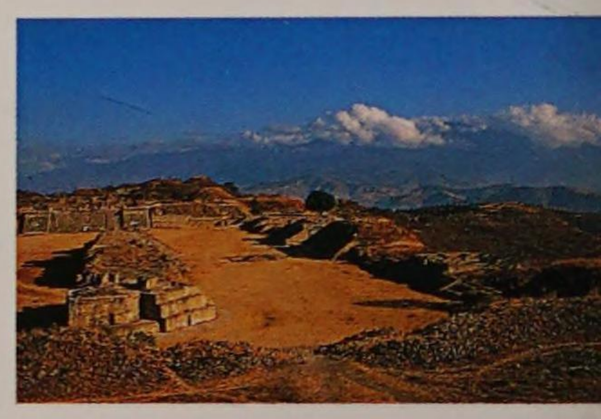
Winged flight
In Greek mythology, Daedalus and Icarus wore wax and feather wings to escape a labyrinth. But when Icarus flew too close to the Sun, the wax melted and he fell.



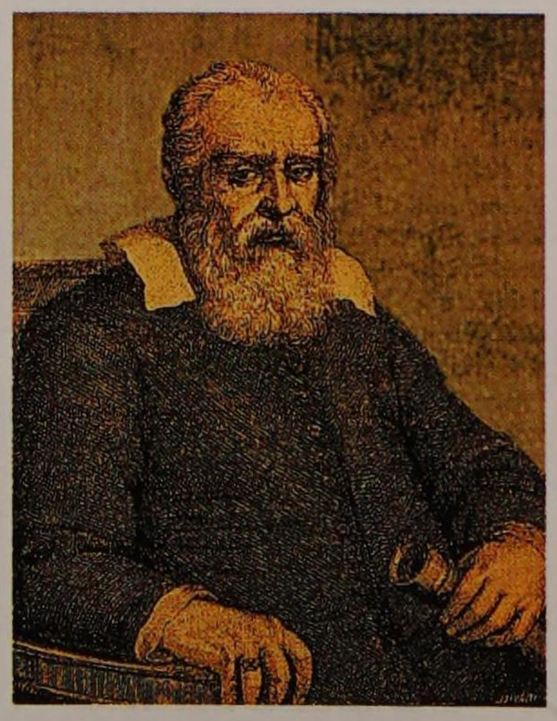
Goose travel
The Moon, Earth's closest neighbor, is the object of many dream journeys into space. In a 17th-century story, wild geese carried a man to the Moon.



Fact meets fiction
As humans learned more about space, stories about space travel increased. The 19th-century author Jules Verne wrote about people being fired to the Moon by a giant cannon.

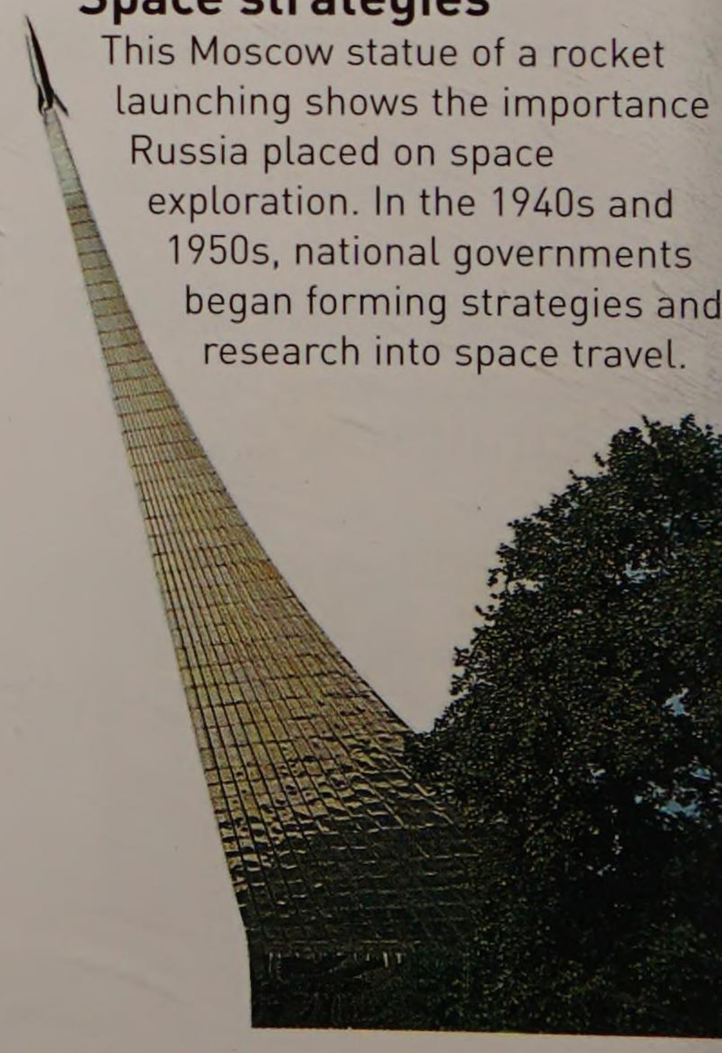


Sky watching
Some of our knowledge of space comes from ancient civilizations. Thousands of years ago, the movements of the Sun, Moon, and planets were used for timekeeping.



Telescope power
Until the 17th century, people believed that everything in space revolved around Earth. But Italian astronomer Galileo Galilei used a telescope to show that Earth was not at the center of the universe.

Music of space
Space, the Moon, planets, and the stars have all inspired writers, poets, and musicians.
In 1916, Swedish composer Gustav Holst wrote an orchestral suite called "The Planets."
In 1964, singer Frank Sinatra (left) sang "Fly Me to the Moon."



Space strategies
This Moscow statue of a rocket launching shows the importance Russia placed on space exploration. In the 1940s and 1950s, national governments began forming strategies and research into space travel.

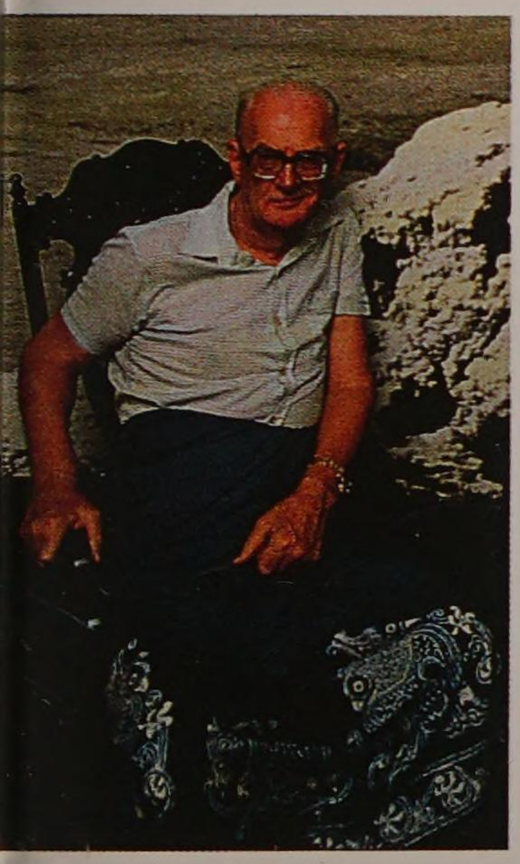
Comic capers

Authors and artists let their imaginations run wild in space comics from the 1930s through to the 1950s. Alien encounters were regularly featured.

Comic of men on the Moon

Space pop

Fashion and popular music of the 1960s and 1970s showed the influence of the space age. David Bowie (right) called himself Ziggy Stardust and wrote songs such as "Is There Life on Mars?".



Club together

From 1927, clubs dreaming of space travel were formed in Germany, the US, and Britain. A leading figure in the British club was writer Arthur C. Clarke, whose ideas influenced space research. He foresaw the use of satellites for global communication and showed us the space future in his books, articles, and the film *2001: A Space Odyssey*.

Earth

Cratered surface

Astronaut with flag

Space sculpture

In 1986, this sculpture of humans conquering space replaced the medieval figures on Britain's York Minster Cathedral after they were destroyed in a fire.

Space heroes

Today's children know that space exploration is a reality. They understand how a satellite works, they know what space is like, and they look forward to exploring it.

What is space?

Surrounding Earth is a blanket of air, its atmosphere. It provides our oxygen and protects us from the Sun's heat and cold, sunless nights. Away from Earth's surface, the air thins and the temperature changes. Space is about 600 miles (1,000 km) from Earth, but space conditions can be experienced after a few hundred miles. Astronauts 60 miles (100 km) above Earth are said to be in space.

Dusty danger

Dust specks move through space faster than bullets. This metal has been damaged by a piece of nylon traveling at the speed of a space dust speck.

Lead with large hole

Steel with smaller hole

Weightless astronauts in their craft

Weightlessness

Astronauts cannot see or feel gravity, but their spacecraft is constantly being pulled by Earth's gravity.

Passengers experience weightlessness on steep rides

Rigil Kentaurus in the night sky

The Milky Way Galaxy

Roller coaster

Passengers can experience weightlessness in a roller coaster or a car going over a hump in the road. Astronauts train in 25 second weightless periods inside modified aircraft.

Looking into space

The night sky contains the tens of thousands of stars in the Milky Way Galaxy. All are like our star, the Sun. Beyond the Milky Way are more than 100 billion stars in other galaxies, and trillions of miles of empty space. The Sun and eight planets make up our solar system.

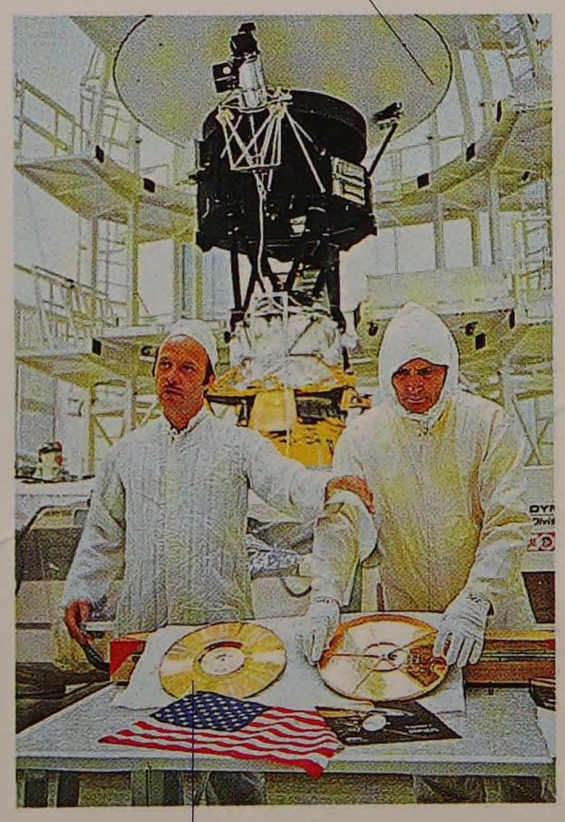
Space travel

Most astronauts have traveled into space close to Earth, where they use the planet's gravity to orbit it. Only 24 have traveled farther, to the Moon.

Suits withstand temperatures from 250°F (121°C) to −150°F (−101°C)

Martian rock that fell to Earth

The Voyager spacecraft prepares for launch



Disk with message

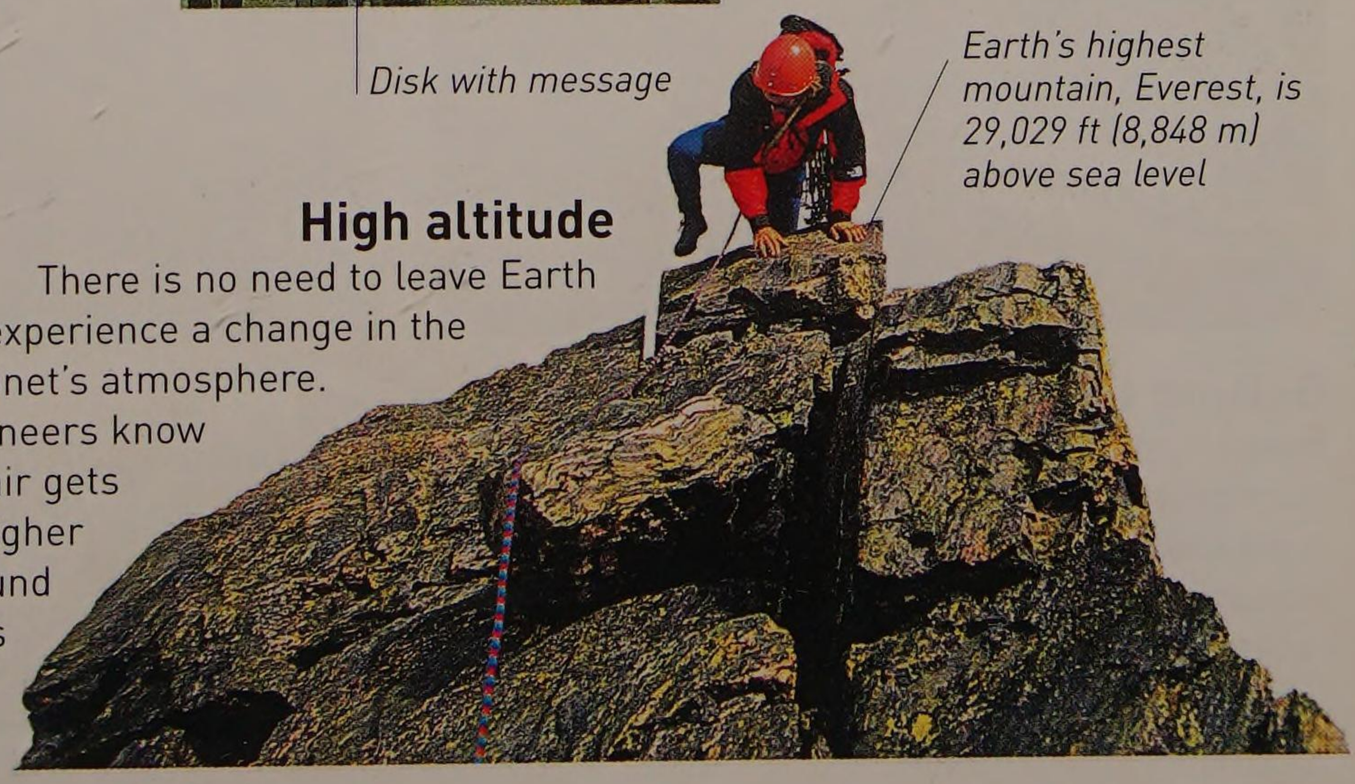
Down to Earth

Scientists study space material collected by robotic craft and astronauts. They also study some of the 3,000 chunks of space rock that fall to Earth each year.

Earth message

At least one in every 20 stars has planets. Over 3,500 planets have been discovered orbiting other stars. Spacecraft carry messages in case life exists elsewhere.

Earth's highest mountain, Everest, is 29,029 ft (8,848 m) above sea level



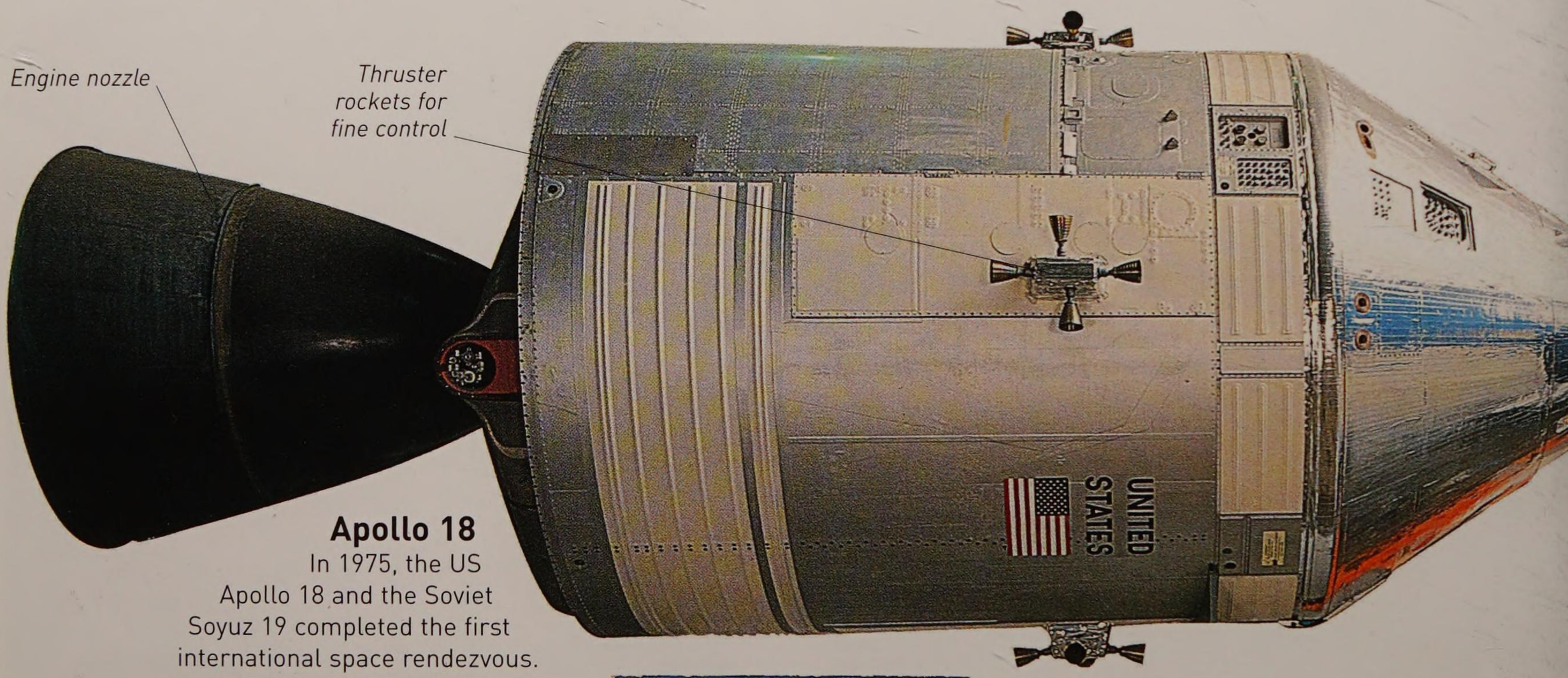
High altitude

There is no need to leave Earth to experience a change in the planet's atmosphere. Mountaineers know that the air gets thinner the higher they climb. At around 12,000 ft (3,700 m), there is less oxygen, and they need to carry their own.

Space nations

People from around the world are involved in space exploration, although the vast majority will never go anywhere near space. Fewer than 10 countries regularly launch vehicles into space, but many more countries manufacture spacecraft and technology, or monitor space activities. Some nations pool their financial resources, knowledge, and expertise. Sending an astronaut, a probe, or a satellite into space takes thousands of people and costs billions of dollars.

Mission patch
Each space mission has its own small, cloth patch, featuring pictures and words. French astronaut Jean-Loup Chretien's stay aboard Salyut 7 in 1982 was marked by this patch.

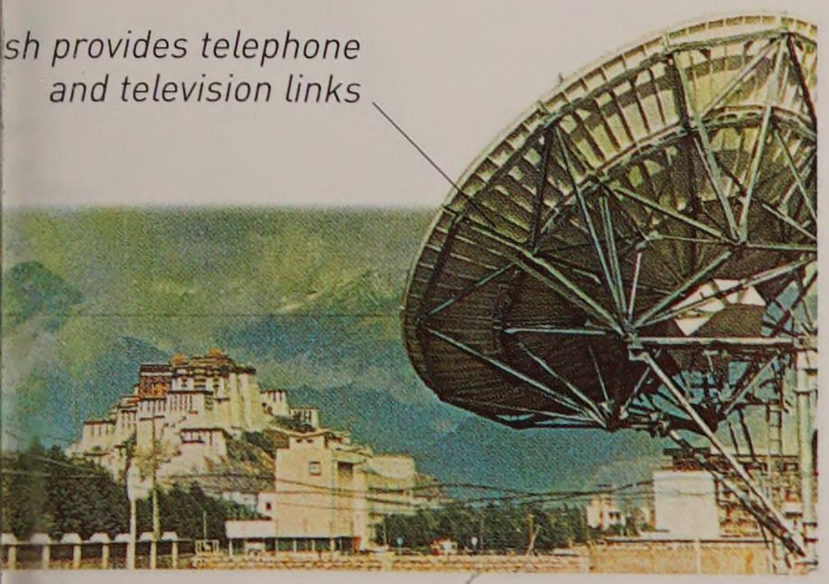


Apollo 18
In 1975, the US Apollo 18 and the Soviet Soyuz 19 completed the first international space rendezvous.

Getting there
Metals and parts used in spacecraft, such as this major part of the Ariane 5 rocket, are produced by different manufacturers. Here, the Ariane 5 rocket part is transported to the launch site at Kourou in French Guiana, South America.

Sounds of space
This two-disk recording was released during the 1975 Apollo-Soyuz docking as a celebration of Soviet achievement. The disks include a space-to-ground transmission and a patriotic song sung by Yuri Gagarin, the first man into space.

Mission control, China
China sent its first satellite Mao 1 into space in 1970, and its first taikonaut (Chinese astronaut) in 2003. This picture shows mission control staff at the Xichang site practicing launch procedure.



he ears of the world

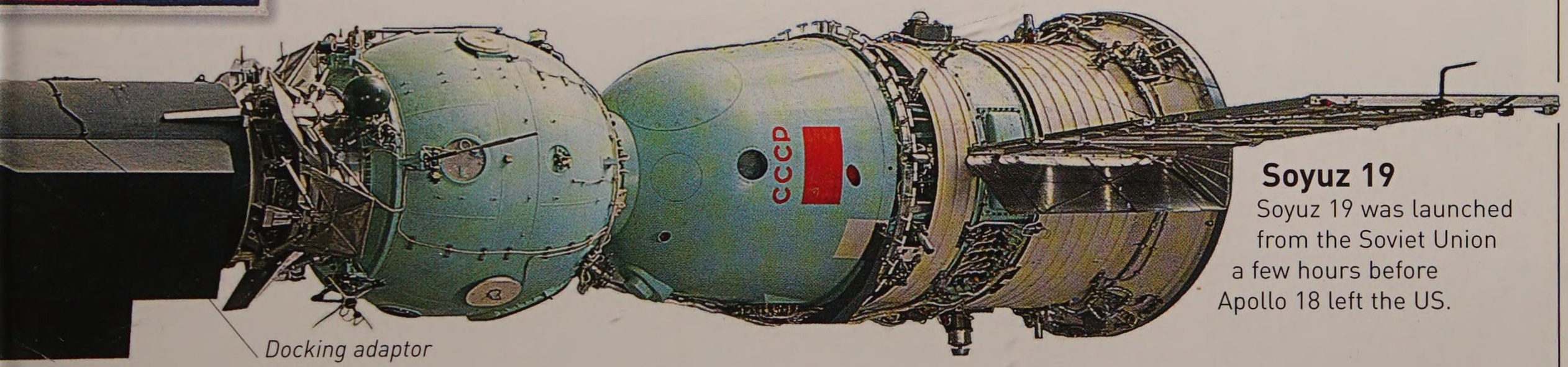
ant dishes around the world collect data ansmitted by planetary probes, satellite bservatories, and communications tellites. This 39 ft 4 in (12 m) dish in bet is used for telecommunications.

India in space

India launched its first space rocket in 1980. This patch marks astronaut Rakesh Sharma's 1984 mission to Salyut 7.

Headline news

The launch of a country's first astronaut is major news. The flights of Poland's first astronaut, Miroslaw Hermaszewski, in 1978, and Cuba's first astronaut, Arnaldo Tamayo Mendez, in 1980, both made headlines.



Soyuz 19

Soyuz 19 was launched from the Soviet Union a few hours before Apollo 18 left the US.

Docking adaptor

US and Soviet astronauts together

International link

In 1975, Americans and Soviets linked up for the first time in space. Three US astronauts aboard Apollo 18, and two Soviets on Soyuz 19, docked and stayed together for two days as they orbited the world.

Space gifts

International space crews exchange gifts, such as these Russian candies. Space crew aboard Mir greeted visiting astronauts with a traditional Russian gift of bread and salt.

Prunariu's mission patch

Romania in space

Dumitru Prunariu was the first Romanian into space when he flew on Soyuz 40 to the Salyut 6 space station in 1981. Along with Soviet astronaut Leonid Popov, Prunariu underwent psychological and medical tests.

Gurragcha's mission patch

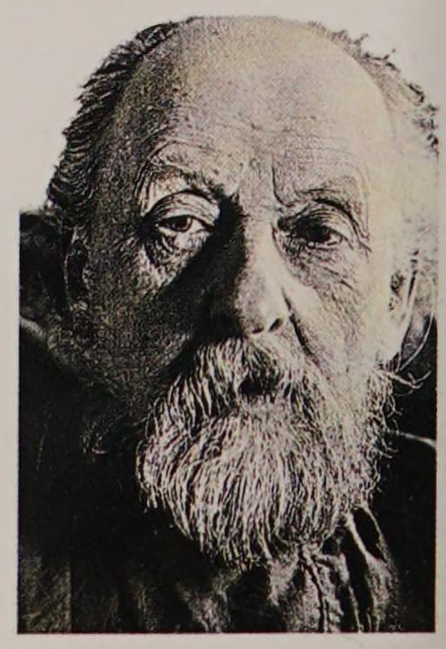
Searching Mongolia

Mongolian astronaut Jugderdemidiyn Gurragcha stayed aboard the Salyut 6 space station for eight days in 1981. He conducted a number of experiments. Using mapping and cameras, he searched for ore and petroleum deposits in Mongolia.

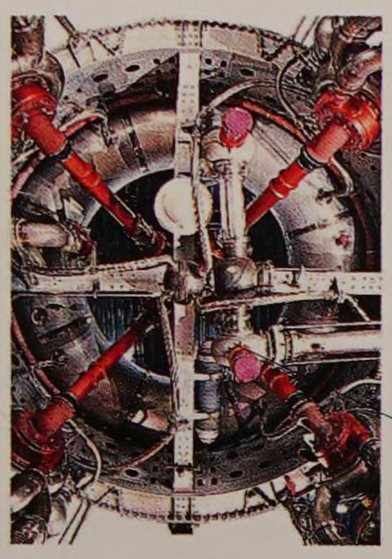
Rocket science

A rocket is needed to launch anything and anyone into space. It provides the power to lift itself off the ground and reach the speed to carry it away from gravity's pull and into space. Hot gases from the burning rocket fuels are expelled through an exhaust nozzle at the bottom of the rocket. This lifts the vehicle off the ground.

Early rockets
The first rockets were used by the Chinese about 1,000 years ago. They were powered by gunpowder. This 17th-century man shoots rocket arrows from a basket.

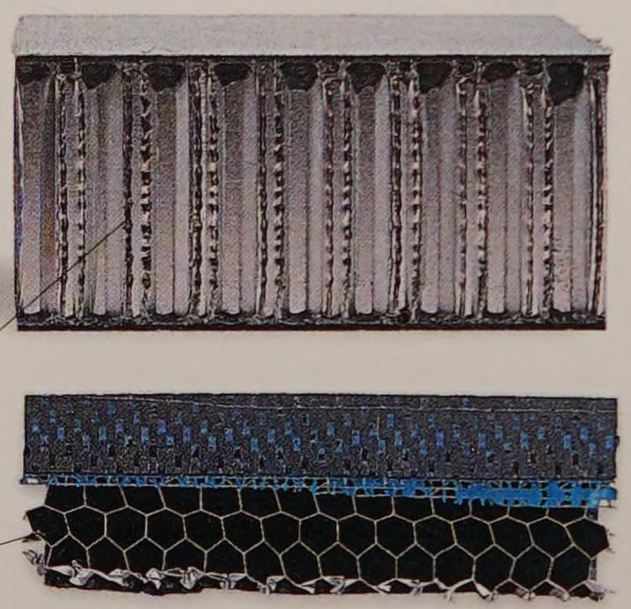


Rocket pioneer
Russian Konstantin Tsiolkovsky worked on rocket theory in the 1880s. He calculated the speed and amount of fuel a rocket would require.



Rocket engine
This is just one of four Viking engines that powered the Ariane 1 rocket—seen from below as it stands on the launch pad.

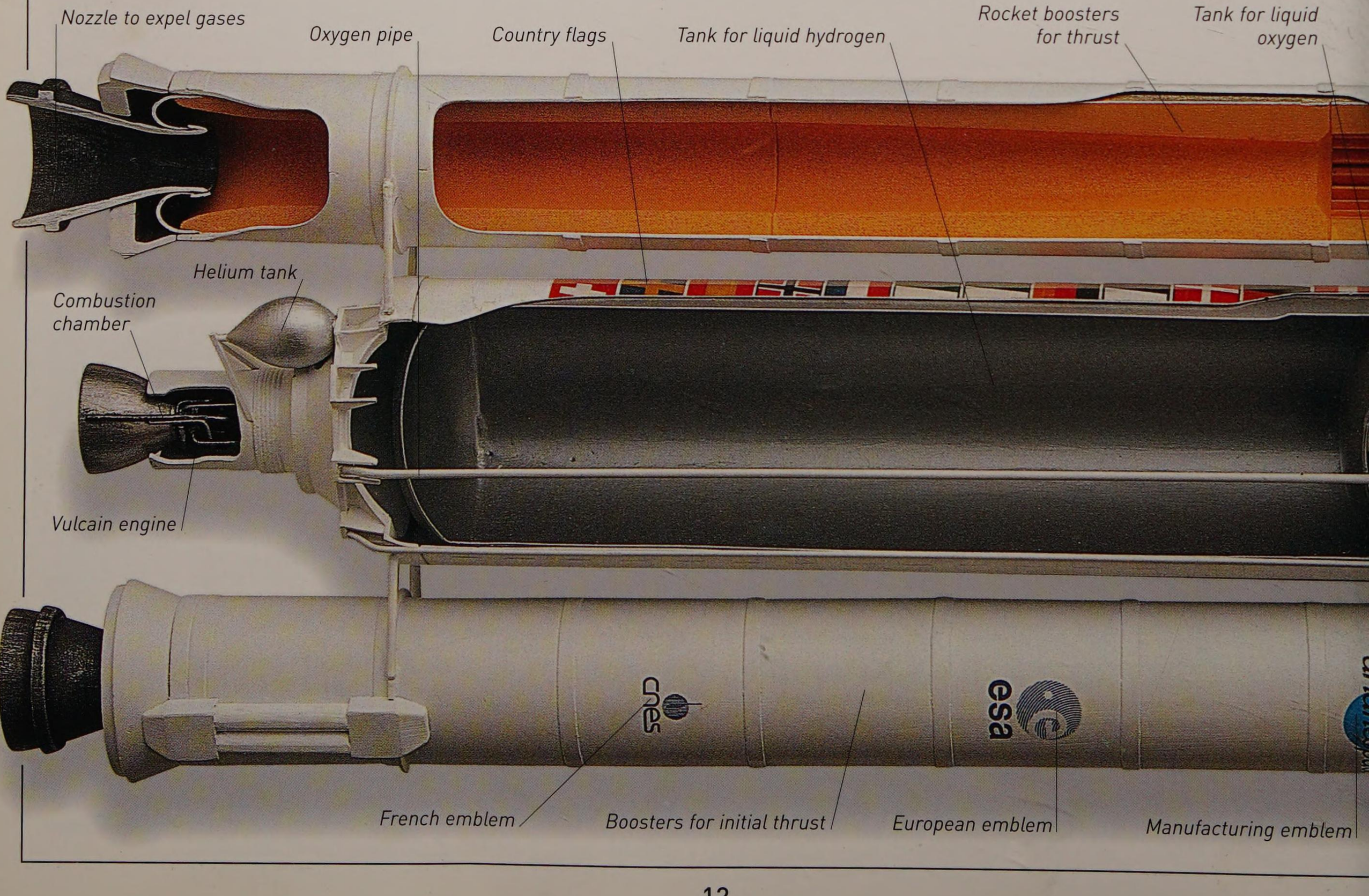
Giant Viking rocket engine



Light and strong honeycomb

Honeycomb structure

Made to measure
The materials used in rockets nee to be light. This is because a lighte rocket needs less fuel to launch it and so is less costly. The material also need to be strong to withstan the thrust at launch. This honeycomb material has been specially developed by scientists and engineers for space rockets.

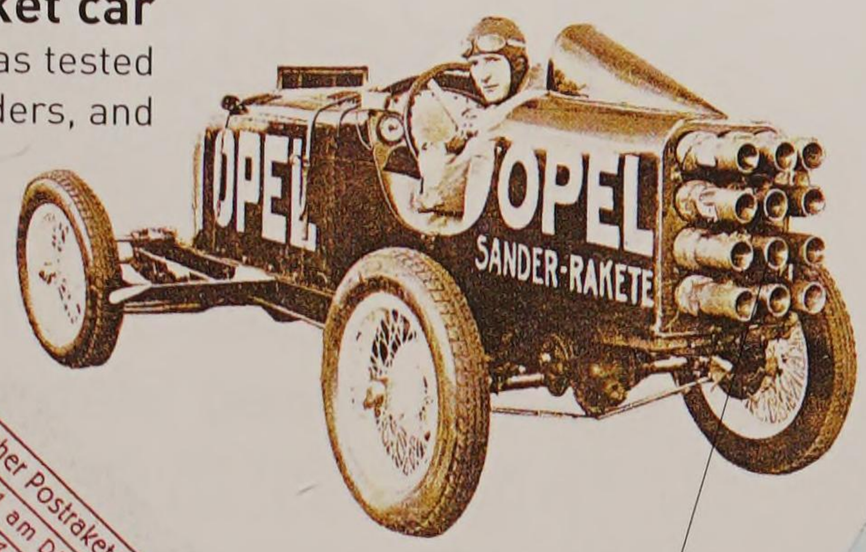


Liquid-fuel rocket

American Robert Goddard launched the first ever liquid-fuel rocket in 1926. The flight lasted two and a half seconds and the rocket reached an altitude of 41 ft (12.5 m).

Rocket car

Fuel for use in rockets was tested in cars, rail vehicles, air gliders, and ice sleds in the 1920s. The cars resembled a rocket in shape and in the noise they made. They used either liquid fuel or powdered solid fuel.

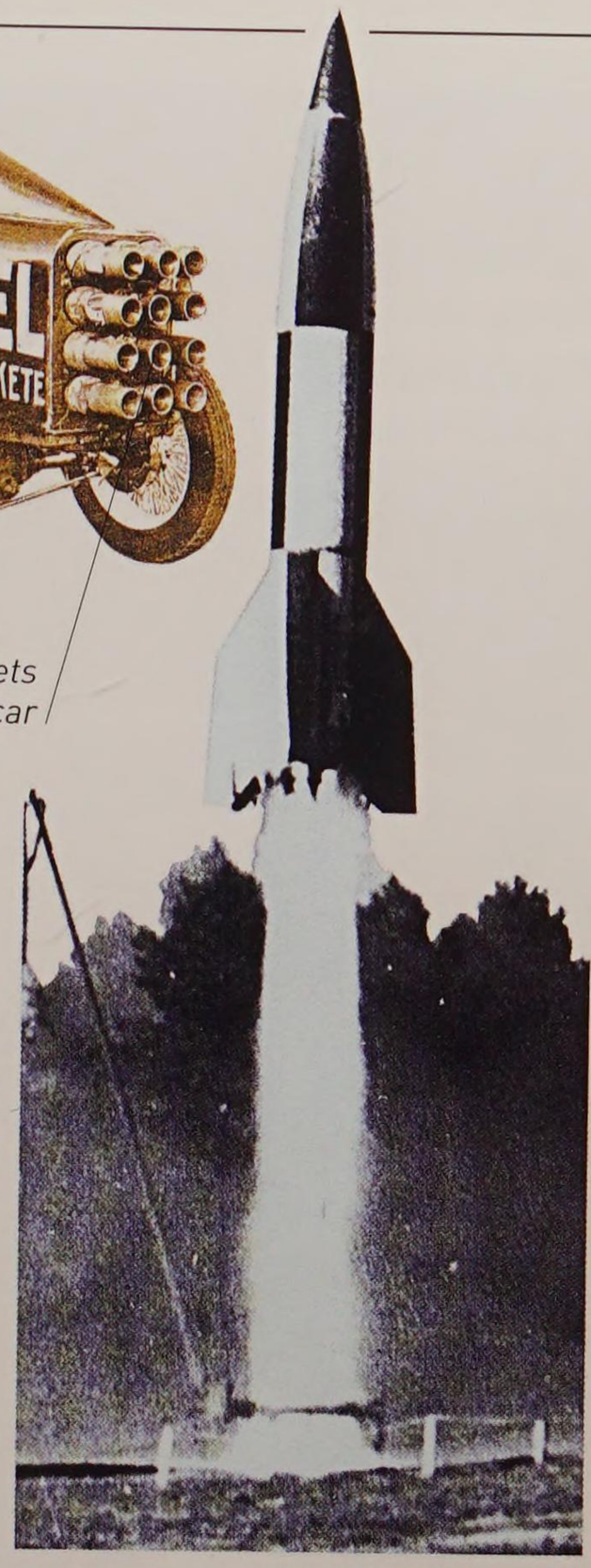


Mini-rockets powered this car

Rocket post

Enterprising ways of using rocket power were developed in the 1930s. These cards were sent across Germany by rocket post in 1931. They were specially produced cards, using distinctive rocket post stamps.

Rocket stamp



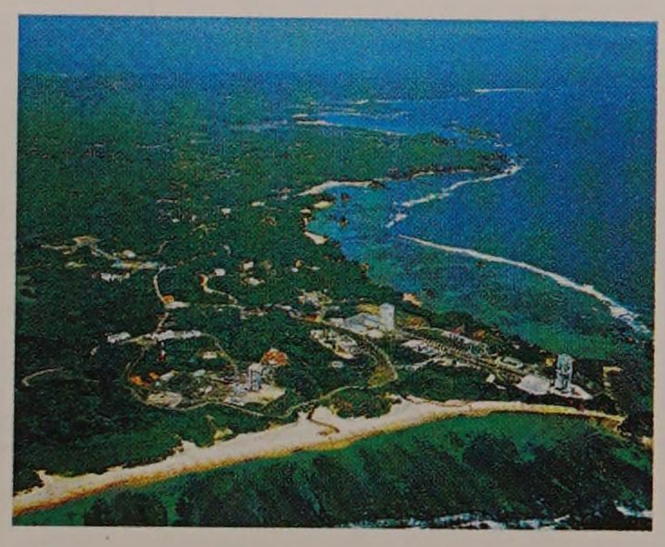
First to space

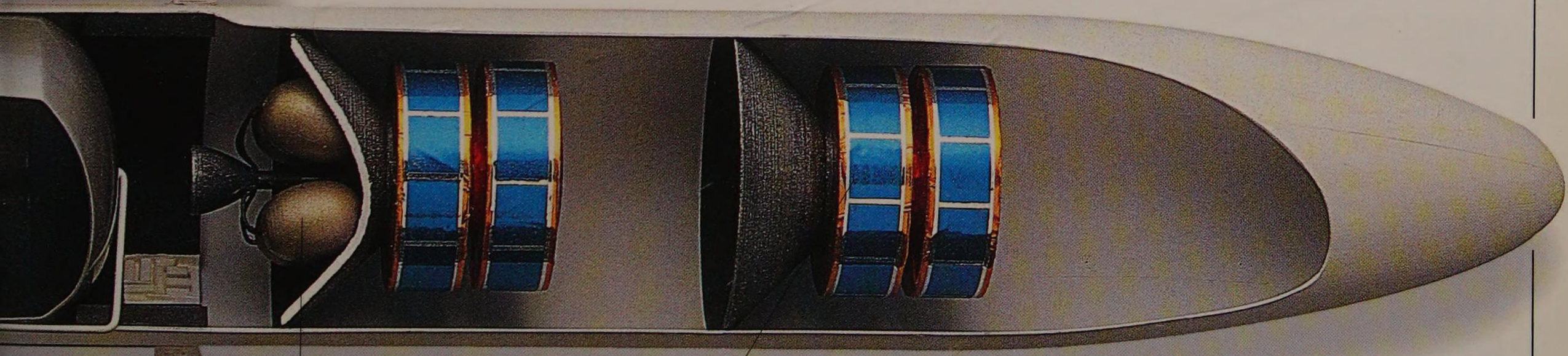
The V2 rocket was developed in Germany and first launched in 1942. The rocket was used as a weapon and more than 4,000 were fired against Britain in World War II. After the war, the V2 and rockets for space travel were developed by an American team headed by Wernher von Braun.

rachute in nose cone

Island to space

Japan's Tanegashima Space Center is one of about 30 launch sites around the world where rockets start their space journeys. Japan became the fourth nation into space when it launched its first satellite in 1970.





Engine to move the satellites into orbit

Satellite to be carried into space

Ariane 5

The Ariane rocket is the launch vehicle of the European Space Agency (ESA). The agency is made up of 20 European countries that develop spacecrafts. More than 200 Ariane rockets have been launched from the ESA launch site at Kourou in French Guiana. The Ariane 5 is powerful enough to launch several small satellites.

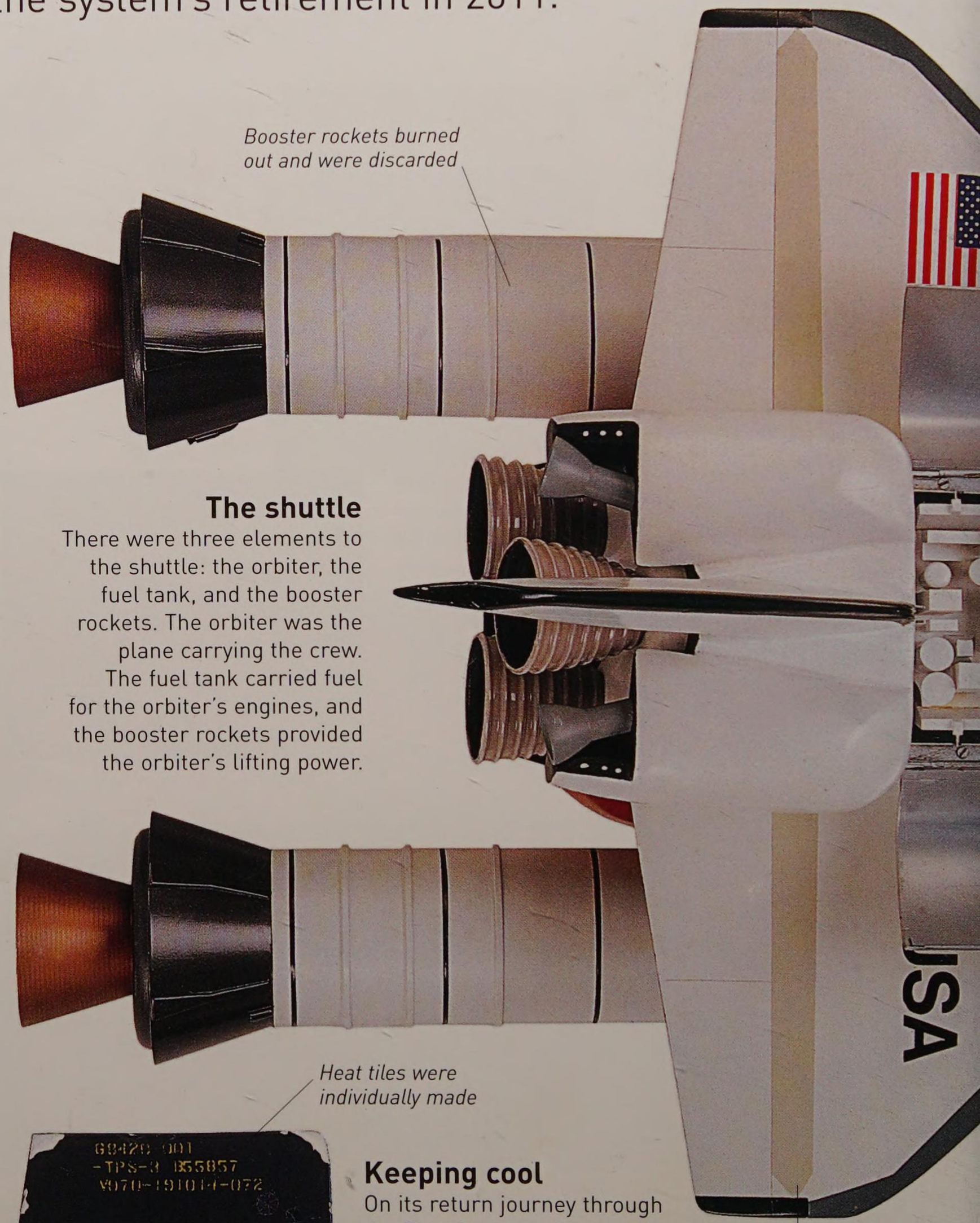
Reusable rocket

When the first space shuttle was launched in 1981, it marked a turning point in space travel. This was when the United States (US) invented a reusable Space Transportation System (STS), or shuttle, for short. Launched like a conventional rocket, the shuttle returned to Earth like a plane. Shuttles carried out 135 missions from 1981 until the system's retirement in 2011.

Piggyback
A shuttle was transported to a launch site piggyback style on top of a specially adapted Boeing 747 aircraft. The shuttle was then prepared for launch and equipped with boosters and a fuel tank for liftoff.

Blastoff
Within two minutes of the shuttle's liftoff, its booster rockets were discarded, followed by its fuel tanks six minutes later. Within 10 minutes, it was in space. Atlantis, shown here, made the final shuttle flight in 2011.

Safe inside
Inside the shuttle's fuel tank, shown here, were two pressurized tanks that contained liquid hydrogen and liquid oxygen. This fuel was fed to the orbiter's three engines.



The shuttle
There were three elements to the shuttle: the orbiter, the fuel tank, and the booster rockets. The orbiter was the plane carrying the crew. The fuel tank carried fuel for the orbiter's engines, and the booster rockets provided the orbiter's lifting power.

Keeping cool
On its return journey through the Earth's atmosphere, the shuttle could reach temperatures of 2,474°F (1,357°C). Heat-absorbent tiles protected the shuttle.

Hypersonic aircraft

During the 1960s, the X-15 rocket-powered aircraft investigated flight at hypersonic speeds. The pilot controlled the X-15 at about 4,000 mph (6,500 kph).

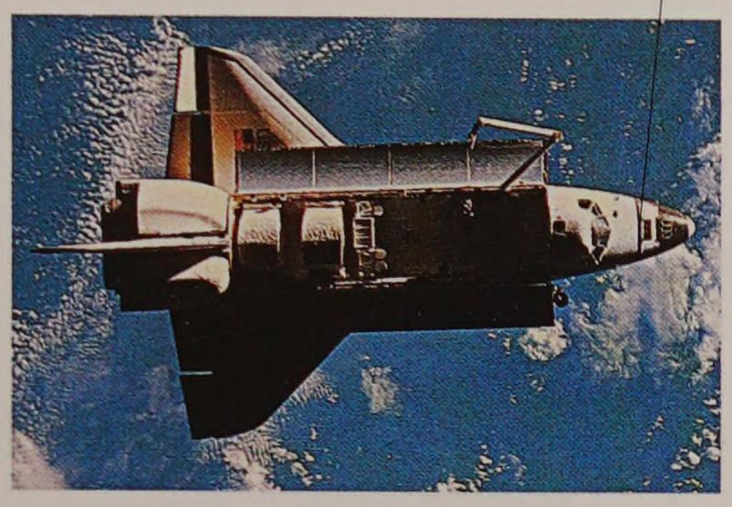
Soviet shuttle

The Soviet Union was the only other country besides the US to build a shuttle. In 1988, the unmanned Soviet shuttle Buran flew two orbits of Earth and returned by automatic landing.

On board is first US female astronaut, Sally Ride

Orbiters

The US orbiters included Columbia, Discovery, Atlantis, and Endeavour. Challenger, shown here, flew nine times before exploding in 1986.



Shuttle jobs

Each shuttle had a commander responsible for the flight, a pilot to fly the orbiter, and astronaut specialists. Mission specialists looked after the orbiter's systems and performed space walks.

Commander John Young (left) and pilot Robert Crippen

Payload bay doors

Tunnel

Flight deck and crew quarters for up to eight astronauts

External fuel tank was emptied and discarded in the first eight and a half minutes of flight

Booster rockets fell safely into the ocean and was retrieved

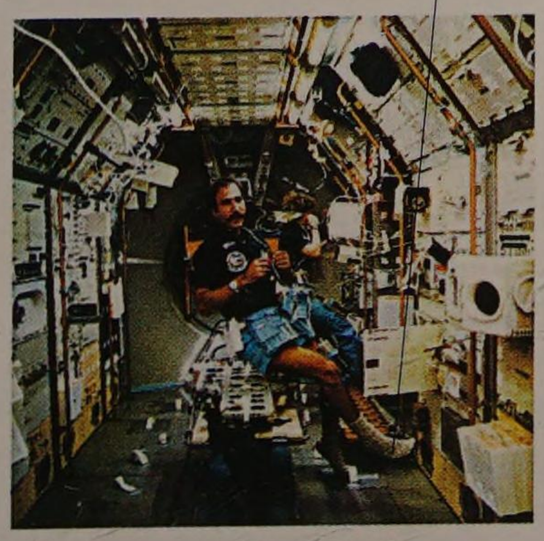
Spacelab

Ockels in his slippers

Parachute to slow orbiter

Spacelab

Wubbo Ockels, a Dutch astronaut, was a payload specialist on Challenger's 1985 mission. During the seven-day flight, he conducted experiments on the human body in the Spacelab.

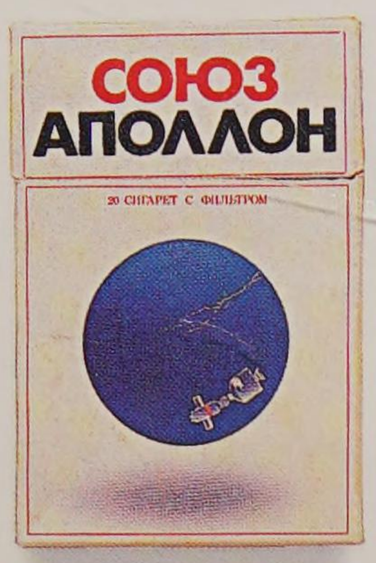


Shuttle landing

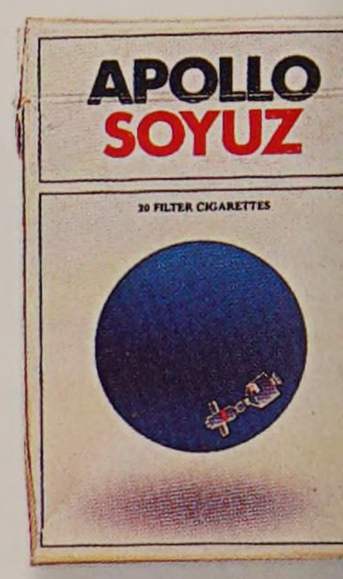
An orbiter's onboard motors were used to maneuver it in space and to position it to come out of orbit and decelerate. The orbiter entered the atmosphere at 15,000 mph (24,000 kph) and touched down at 215 mph (344 kph).

The race for space

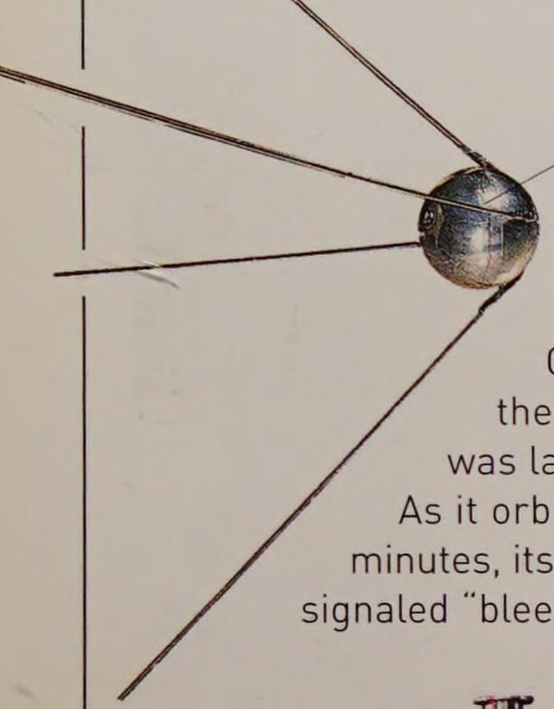
In 1957, the United States and the Soviet Union started a race against each other to achieve success in space. Each wanted notable firsts: to be the first to put a satellite into space; to have the first astronaut in orbit; to make the first space walk; and to be the first to step on the Moon. The race got under way when the Soviets launched Sputnik 1, proving their space capability to the surprised Americans.



Space cigarettes
These cigarettes celebrate the 1975 docking of the US Apollo 18 and the Soviet Soyuz 19.

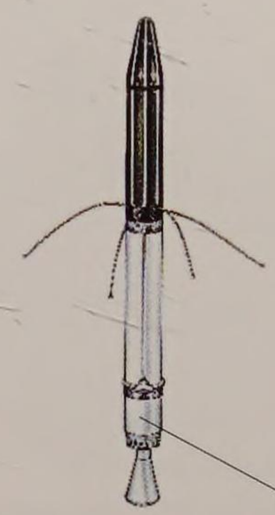


Apollo-Soyuz cigarettes written in English and Russian



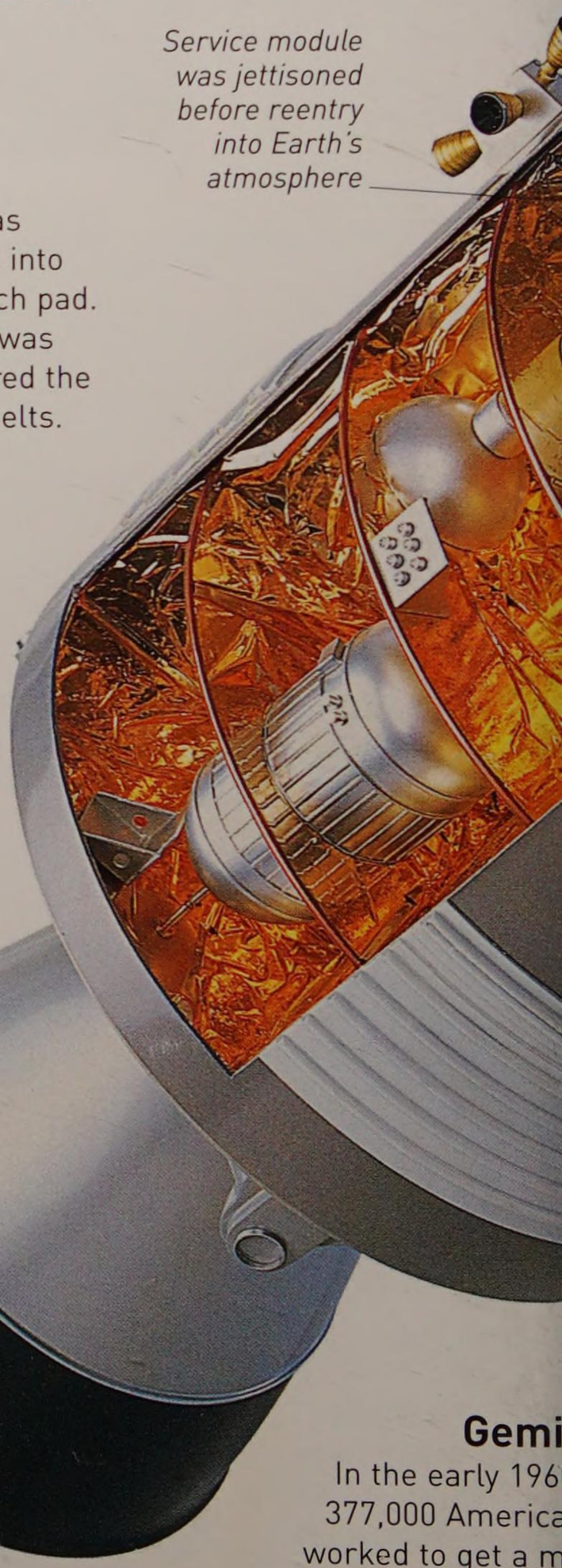
Aluminum sphere 1 ft 11 in (58 cm) across

Sputnik 1
On October 4, 1957, the first artificial satellite was launched by the Soviets. As it orbited Earth every 96 minutes, its two radio transmitters signaled "bleep bleep."



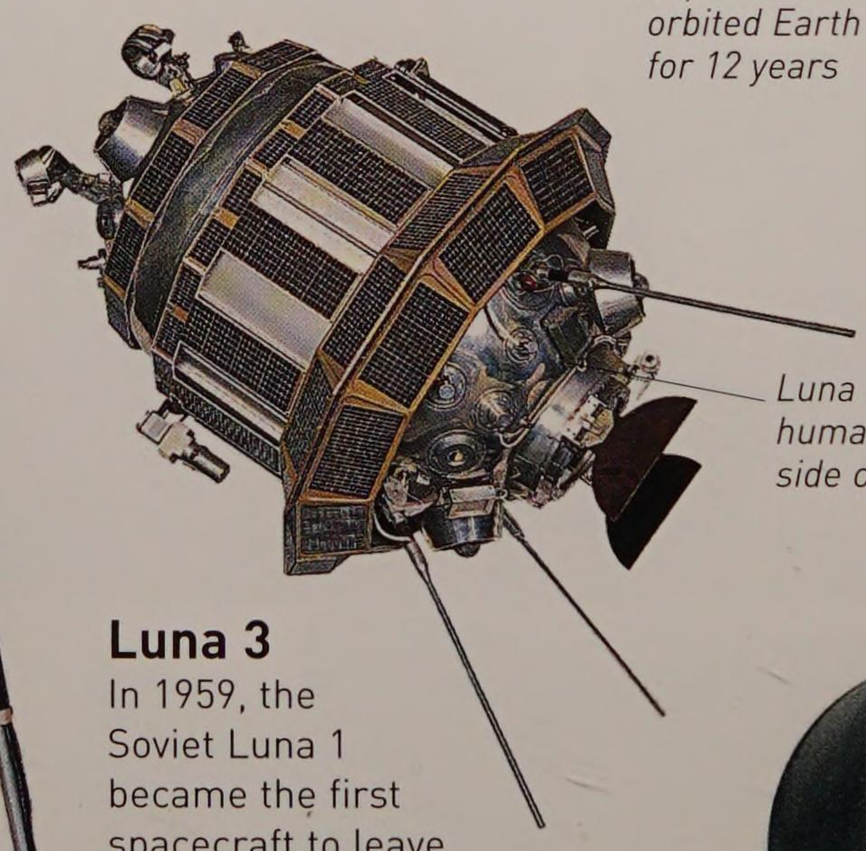
Explorer 1
Vanguard, the rocket that was to carry the first US satellite into space, exploded on the launch pad. Instead, satellite Explorer 1 was launched in 1958. It discovered the Earth's Van Allen radiation belts.

Explorer 1 orbited Earth for 12 years



Service module was jettisoned before reentry into Earth's atmosphere

A heart monitor was attached to Laika



Luna 3 showed humans the far side of the Moon

Luna 3
In 1959, the Soviet Luna 1 became the first spacecraft to leave Earth's gravity. Luna 9 was the first craft to land on the Moon.

First animal in space
One month after the launch of Sputnik 1, the Soviets launched a dog named Laika into orbit around Earth, aboard Sputnik 2. Laika survived for a few days. The satellite was heavier than anything the Americans were planning and suggested the Soviets were going to send humans into space.

Gemi
In the early 196
377,000 America
worked to get a m
on the Moon. First,
Gemini two-mann
missions successfu
showed that the America
could space-walk, spend ti
in space, and dock cra

First ever

Yuri Gagarin became the first human in space on April 12, 1961. He orbited Earth in Vostok 1 once before reentering Earth's atmosphere. With him is Valentina Tereshkova, the first woman in space.

Hero's welcome

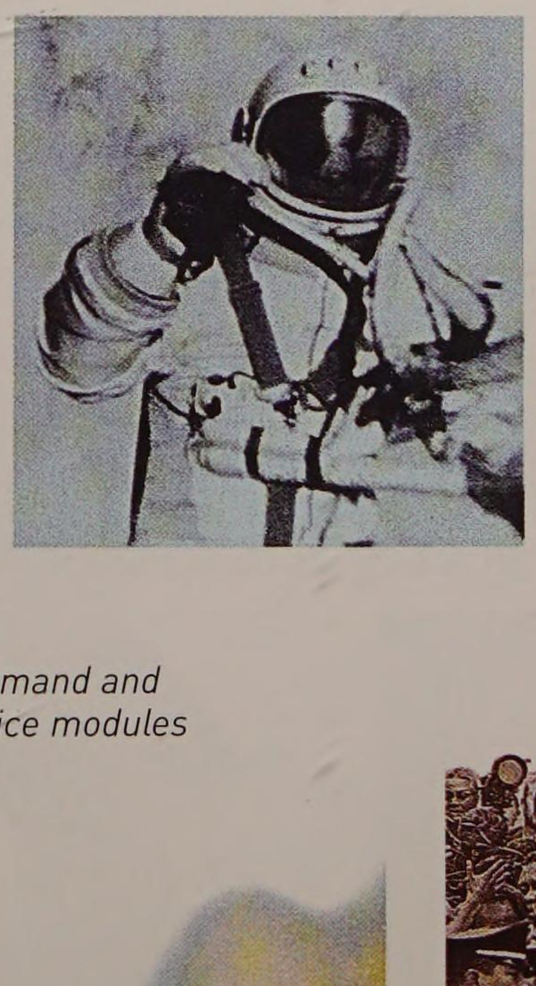
Gagarin's countrymen filled Moscow's enormous Red Square to welcome him home from space. Gagarin was met by crowds wherever he toured in the world.

Three-man crew worked and slept in the command module

Command and service modules

President's promise

In the late 1950s, the US formed the National Aeronautics and Space Administration (NASA). In 1961, the US president, John F. Kennedy, set a goal of "landing a man on the Moon and returning him safely to the Earth" before the decade was out.



First space walk

Once humans had flown into space, the Soviets and the Americans prepared for the first extra vehicular activity (EVA), or space walk. In 1965, Soviet Aleksei Leonov made the first space walk, spending 10 minutes outside his Voskhod 2 craft.

Liftoff

The Saturn V rocket launched the Apollo craft to the Moon. It was as tall as a 30-story building, most of the rocket was fuel. It also contained the lunar module for the Moon landing; the service module with oxygen, water, and power; and the command module.

The Moon to Mexico

Michael Collins, Buzz Aldrin, and Neil Armstrong of Apollo 11, the first mission to land a man on the Moon, are greeted in Mexico City. The three visited 24 countries in 45 days on a goodwill tour after returning from the Moon. Collins orbited the Moon while the others explored the lunar surface.

Space travelers

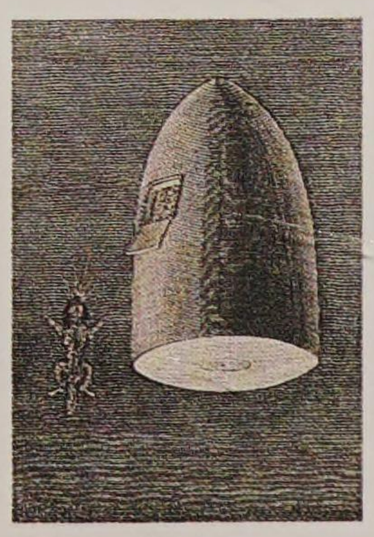


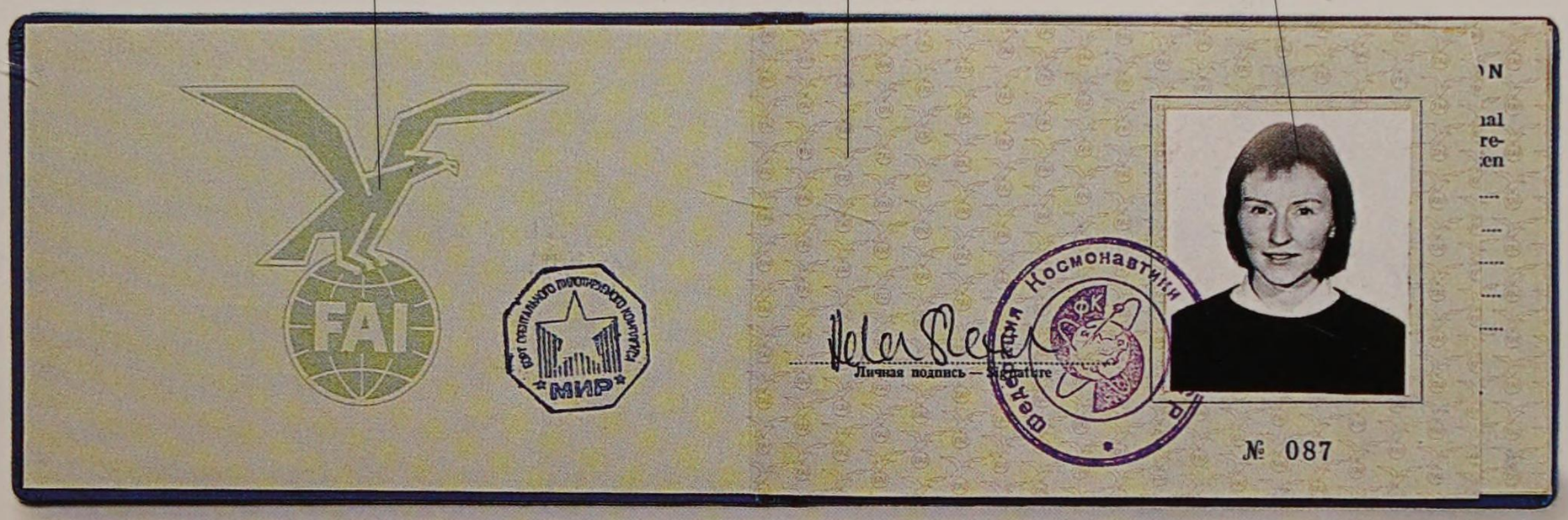
Illustration of a satellite in space

More than 500 people and countless other living creatures have traveled into space. All but the 24 men who went to the Moon spent their time in a spacecraft orbiting Earth. Competition to travel into space is keen. In 2008, 8,400 people applied to become a European astronaut. Astronauts are mentally and physically fit men and women with an outstanding ability in a scientific discipline.

International Aeronautical Federation symbol

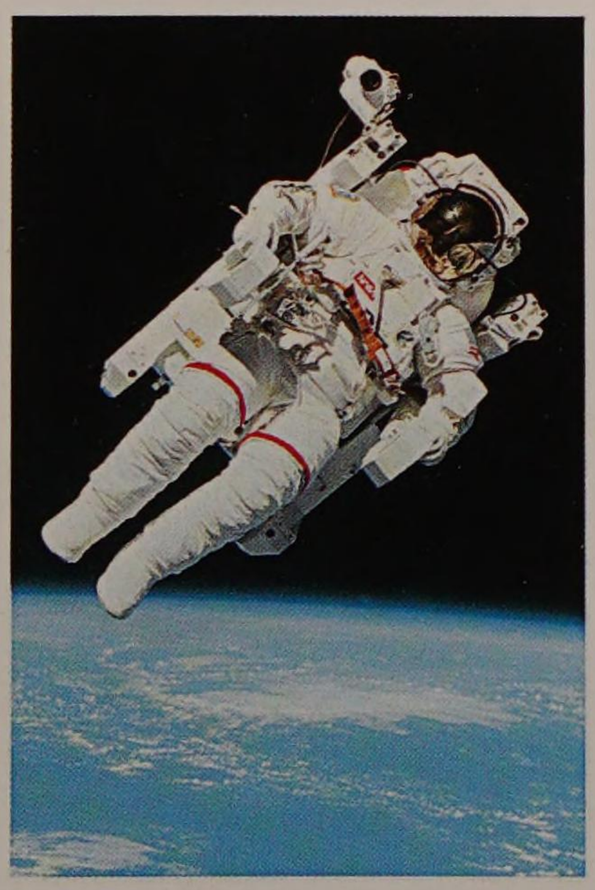
Passport requests that help be given to the holder

British astronaut Helen Sharman



Passport to space

Astronauts can carry a passport for space travel in case it is needed when they return to Earth. An unscheduled landing may be made in a country other than that of the launch. The type shown here is carried by those on board Russian craft.



American Bruce McCandless uses a hand-controlled MMU

Untethered flight

The manned maneuvering unit (MMU) was a powered backpack first used in 1984. The MMU let astronauts move freely in space.

Ham the chimp

Ham the chimp

Chimpanzees were chosen for space travel because of their similar genetic makeup to humans. Ham was the first to travel in January 1961. On his return, he was found to be in excellent condition.

Belka

Strelka

Space dogs

The Soviets launched a number of dogs into space, including Laika. Laika died in flight, bu the dogs Strelka and Belka returned safely to Earth by parachute

Honeybees

In 1984, honeybees traveled aboard the space shuttle Challenger. The bees found weightlessness confusing at first, but then built a successful hive.

Ear frogs

More than 30 years ago, two bullfrogs orbited Earth to help medical research into the workings of human inner ear. The frogs were monitored over a five-day period in both weightless and partial-gravity conditions.

Monkey

In 1958, Gordo became the first monkey into space. Since then, dogs, flies, fish, ants, frogs, sea urchins, and more than 2,000 jellyfish have all traveled into space.

Animal and human crews have backups, to replace anyone that is sick. This backup is drinking some juice.

eady for space

arly animal travelers wore their wn spacesuits. Dogs were chosen ecause they are patient creatures nd their blood circulation and spiration are close to our own.

White rat

Hector the rat visited space in 1961. He soared 100 miles (160 km) into space, and landed safely back on Earth three minutes later.

Space zoo

Monkeys, snails, beetles, and fruit midges traveled in their own capsule on board the Vostok rocket in 1996. After a two-week trip into space, they were tested for the effects of weightlessness before returning to their Earth zoo. Bone tissue taken from the monkeys' hip bones was used for medical research.

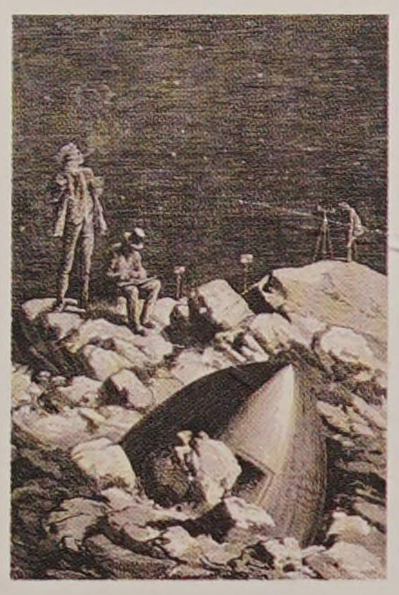


Illustration from Jules Verne's novel *All Around the Moon*

Man on the Moon

The Moon is the only world that humans have landed on outside their own. Twelve US astronauts touched down on the Moon between 1969 and 1972 and spent just over 300 hours on the Moon's surface—80 hours of that outside the landing craft. They collected rock samples, took photographs, and monitored the Moon's environment.

Apollo 16 lunar module, code-named Orion

Upper part of Orion, which is where the astronauts lived while on the Moon

Landing platform remained behind when Orion blasted off the Moon to Earth

Lunar module is shown from behind

Flag with a telescopic arm to keep it extended on the airless Moon

Tongs

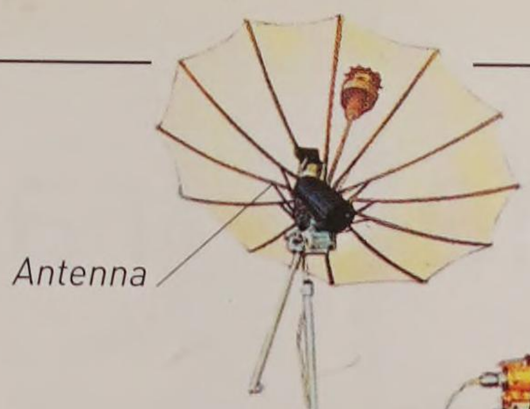
Sample bag

Scoops

Sample return container

Moon tools

Astronauts used gripping tools to collect rock rom the Moon's surface, although the pressure side their space gloves caused aching forearms.



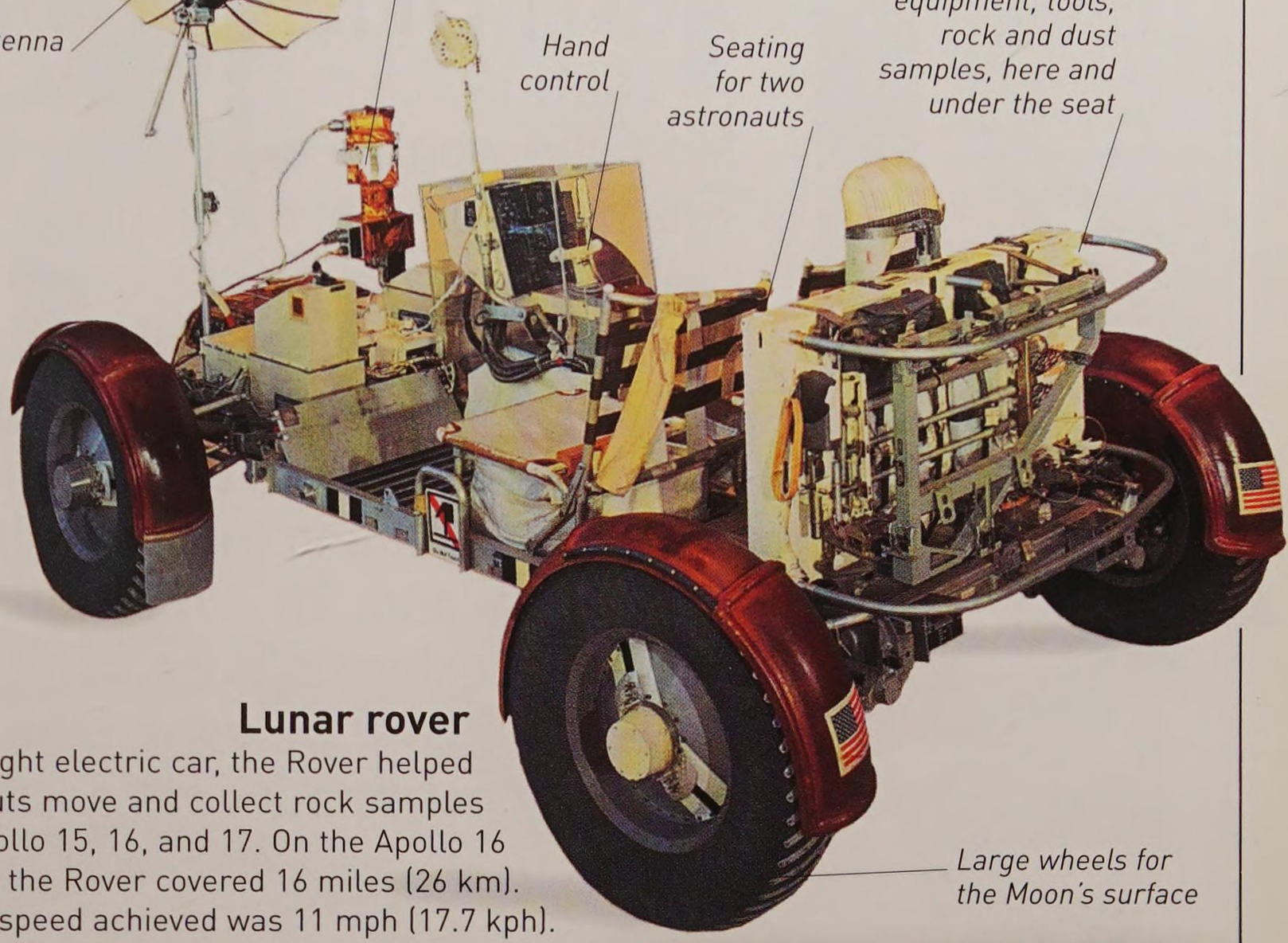
Antenna

Television camera

Hand control

Seating for two astronauts

Room for equipment, tools, rock and dust samples, here and under the seat



Large wheels for the Moon's surface

Lunar rover

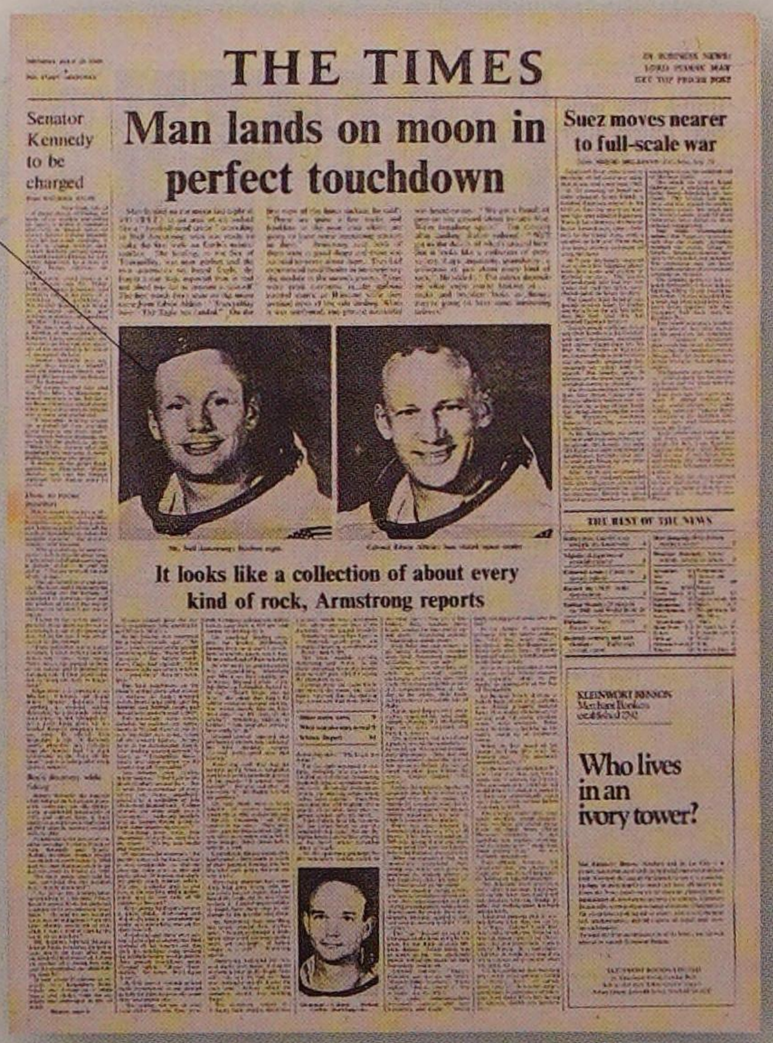
A lightweight electric car, the Rover helped the astronauts move and collect rock samples on Apollo 15, 16, and 17. On the Apollo 16 mission, the Rover covered 16 miles (26 km). The top speed achieved was 11 mph (17.7 kph).

Moon rock

Most of the rock collected on the Moon is volcanic. It dates from around 3.5 billion years ago.

Apollo 16's John Young

Neil Armstrong (left) and Buzz Aldrin (right)



THE TIMES

Senator Kennedy to be charged

Man lands on moon in perfect touchdown

Suez moves nearer to full-scale war

THE BEST OF THE NEWS

It looks like a collection of about every kind of rock, Armstrong reports

Who lives in an ivory tower?

Worldwide headlines

The world held its breath in July 1969 as Apollo 11 neared the Moon's surface. The successful landing was reported in newspapers and on the radio and television all over the world. Many people watched the landing on public screens and at home.

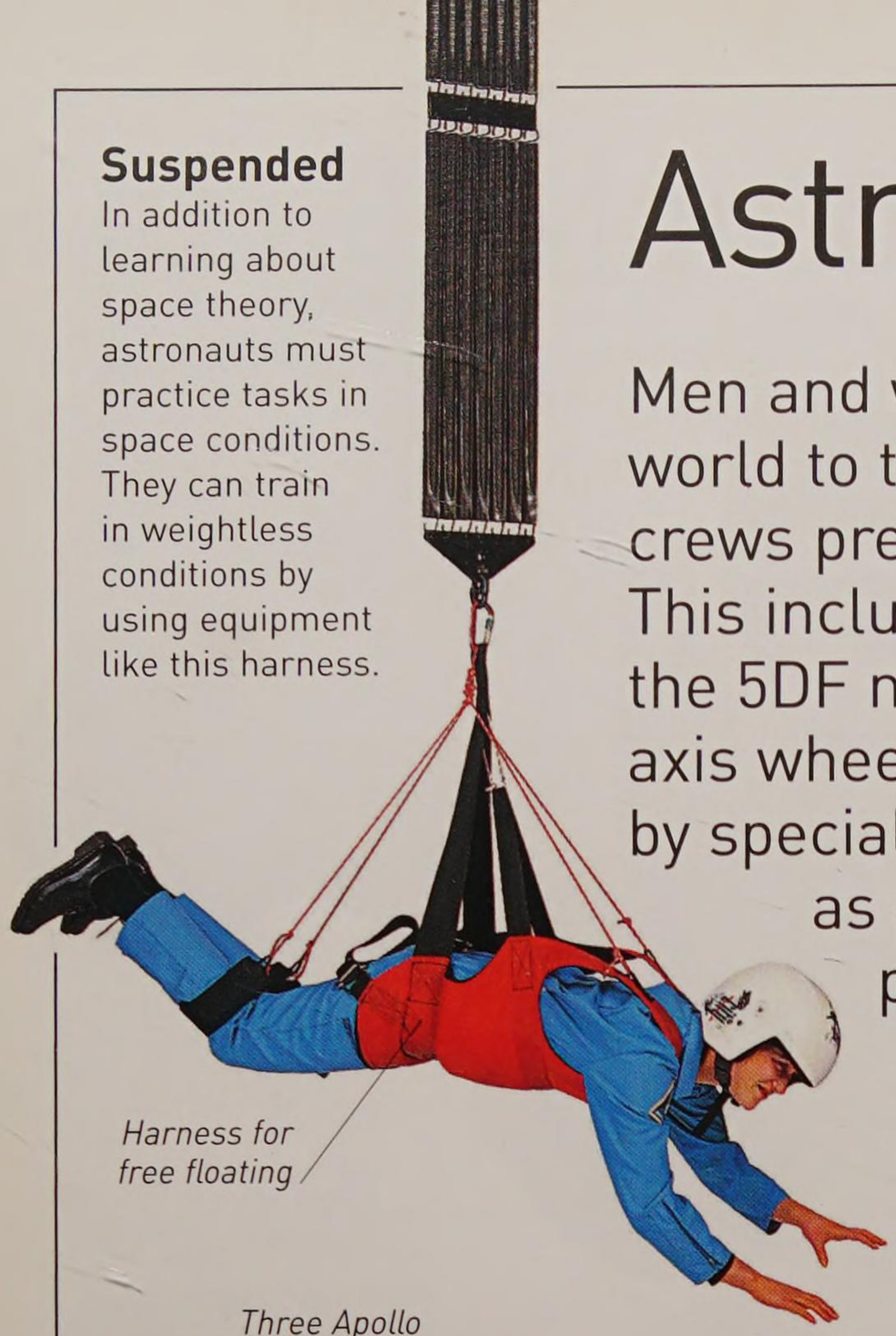
Apollo 16 Moon landing

The Apollo craft landed at six different sites. The first three landings were close to the Moon's equator, but later missions traveled farther. Apollo 16 landed in the Descartes region, where John Young and Charles Duke explored for three days.

Astronaut training

Men and women are chosen from around the world to train for traveling in space. All space crews prepare with classroom and practical training. This includes using simulators such as the harness, the 5DF machine, the moon-walker, and the multi-axis wheel. A year's basic training is followed by special training for a role in space, such as a pilot, or a mission specialist who performs extra vehicular activity (EVA). Only then the successful astronauts are assigned to a flight.

Suspended
In addition to learning about space theory, astronauts must practice tasks in space conditions. They can train in weightless conditions by using equipment like this harness.



Harness for free floating

Moon-walke
Walking in a bul spacesuit is difficult the Moon, where grav is one-sixth that Earth's. The Apol astronauts found bun hops the best way to g around the lunar surfac

Three Apollo astronauts in training

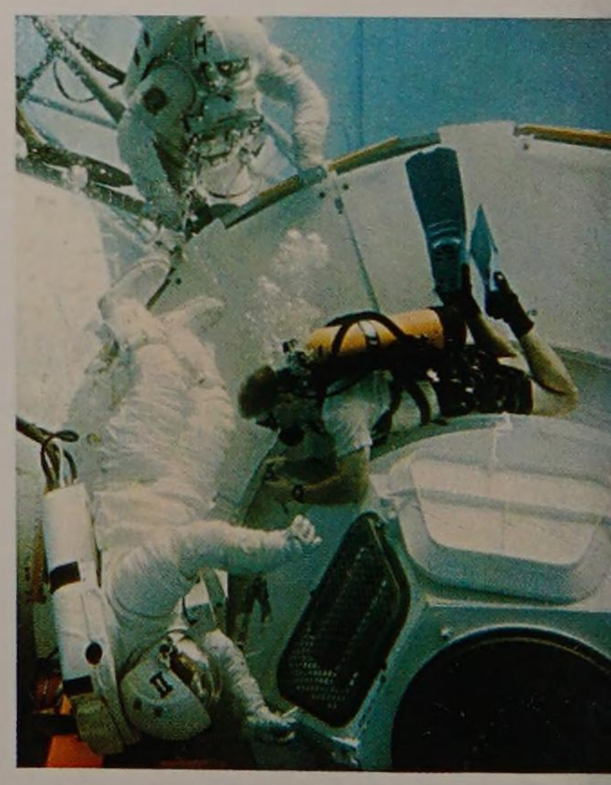
Shelter
Astronauts are trained for any kind of situation, including those when they land back on Earth. These astronauts are making a shelter from leaves.

Life raft
Astronauts receive training in parachute jumping and land and sea survival. Here, Leroy Chiao floats in his life raft.

Simulator gives the astronaut freedom of movement

Feet float over the floor to simulate frictionless movement

Five degrees
The feeling of weightlessness can be simulated in a chair called the Five Degrees of Freedom (5DF) machine, which allows the astronaut to move in all directions, other than up and down, without restraint. Astronauts can also get a 20- to 30-second taste of weightlessness aboard a modified KC-135 jet aircraft.



Train underwater
Spacesuited astronauts train for EVA in large water tanks, where the sensation of gravity is reduced. Here, engineers work on a space station mock-up.

Astronaut walks forward by taking steps

Chair moves as astronaut walks

Harness keeps astronaut upright

Chair is suspended by a large spring

Cage spins inside this spinning wheel, set inside a second spinning wheel

Securely held astronaut tries to write as she is spun around

Multi-axis wheel

Astronauts prepare for the increased gravitational forces during launch and reentry by being spun in a centrifuge machine. This multi-axis machine simulates out-of-control spinning.

Astronaut fashion

A spacesuit is like a portable tent that protects an astronaut. The first suits were designed for astronauts who did not leave their spacecraft. Their suit stayed on for eating, sleeping, and going to the bathroom. Next, an outside suit provided a life-support system and protection against extreme temperatures. Today's astronauts have outside suits and casual inside clothes.

Mobile man
The first spacesuits were based on high-altitude suits worn in jet aircraft. The Apollo suits for the Moon had molded rubber joints, as shown in this toy from 1966.

Male underwear

Device for collecting urine

Space underwear
Coping with human waste presents a tricky design problem. Any collecting device needs to keep the astronaut comfortable but dry at the same time.

Urine storage

Life-support system

1961 Yuri Gagarin suit

1980s Mir space station suit

The first outside suit, used by Aleksei Leonov in 1965

Oleg Makarov's suit

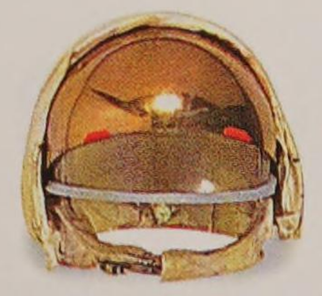
All-in-one overshoe with sole and heel

Overshoe kept in place with fasteners

Changing fashion
A spacesuit's job is to protect an astronaut and allow him or her to move around easily. Although these requirements have not changed over time, spacesuit design has. Today, new materials and experience have combined to produce a comfortable and efficient suit for modern astronauts.

Designed for the Moon

The Apollo Moon suits had three layers. The first was a lightweight garment with sensors for monitoring body changes. Next, a garment with more than 300 ft (91 m) of tubing circulated water to regulate the astronaut's temperature. On top was a suit made of high-strength synthetic fibers, metals, and plastics. A life-support system was added on the back.



Outer helmet

Pressure helmet

Communications cap

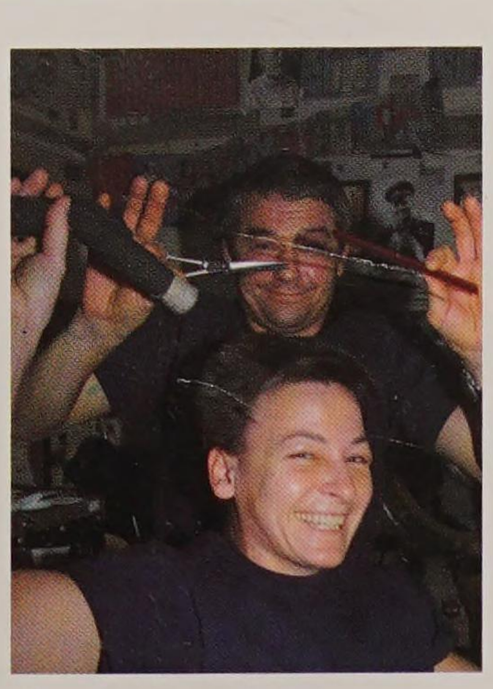
In-flight space clothes

Inside the warm atmosphere of a space station, astronauts wear unisex T-shirts and shorts or jogging-style pants. Socks keep feet warm, but there is no need for shoes. Helen Sharman's in-flight clothes included this one-piece sleeveless suit and jacket.

Gemini suit

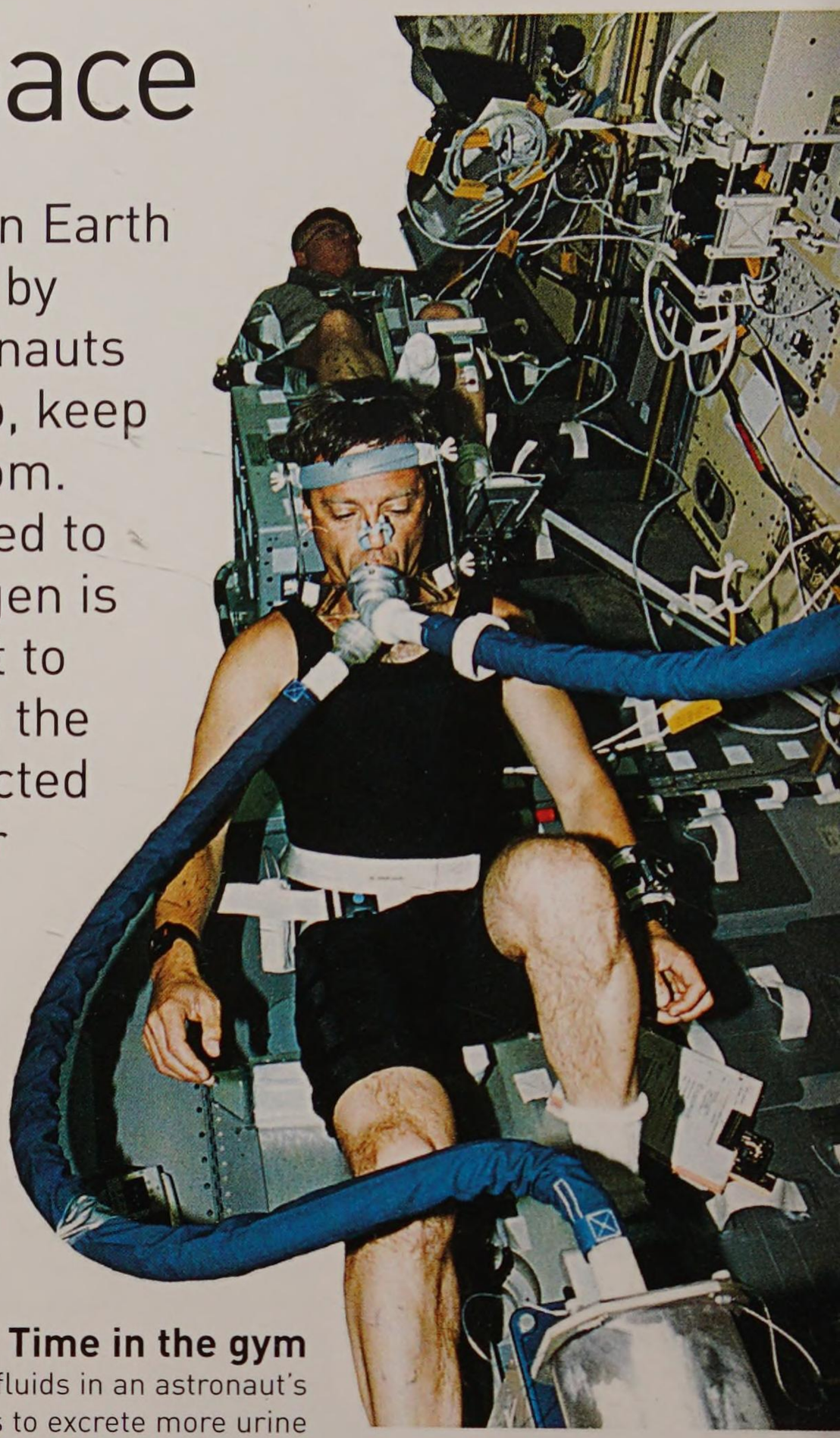
The 1960s Gemini suits were worn by American astronauts walking outside of their spacecraft. Here, a suit is tested out.

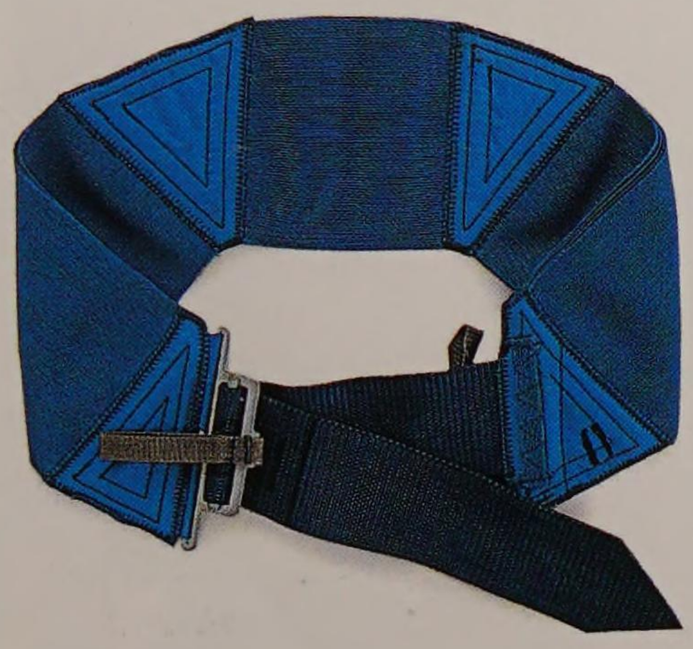
Living in space



Cutting edge
Astronauts spending weeks in space cut each other's hair. The hair clippings must be sucked up before they spread through the spacecraft.

All the things that we do on Earth to stay alive are also done by astronauts in space. Astronauts need to eat, breathe, sleep, keep clean, and use the bathroom. Simple, everyday tasks need to be thought out. Fresh oxygen is circulated around the craft to breathe. Water vapor from the astronauts' breath is collected and recycled for use in experiments and for drinking. Air rather than water is used to suck, and not flush, away body waste.





Under pressure
Body fluids are not pulled down by gravity in space and move up to an astronaut's head. Leg belts help control the flow.

Time in the gym
The upward movement of fluids in an astronaut's body causes the kidneys to excrete more urine and muscles to lose tissue. Here, Canadian Robert Thirsk exercises to counteract these effects.

An astronaut eats 2,800 calories every day

Sweet and sour beef

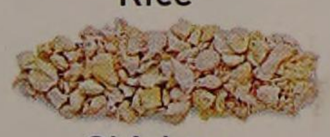
Pineapple

Peach

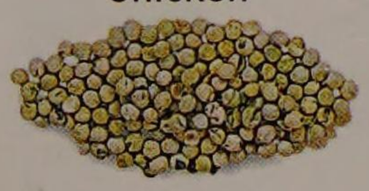
Drinks

Pear

Rice



Chicken



Peas

Fruit and nuts

Almonds

Package menu
Packaged space foods are either ready to eat, or need to be heated or have water added. Foods such as cornflakes, meatballs, and lemon pudding are similar to those found in a supermarket.

Cereals

Food tray is strapped to the astronaut's leg

Hole to tie spoon down

Hygiene

This personal hygiene pouch was issued to British astronaut Helen Sharman for her 1991 stay on Mir. Teeth are cleaned with a brush and edible, foamless toothpaste, or with a finger wipe.

In pens designed for use in space, ink is pushed towards the nib

Astronaut's log

An astronaut's log book contains details of flight procedures. Helen Sharman followed the launch, Mir-docking, and landing in hers.

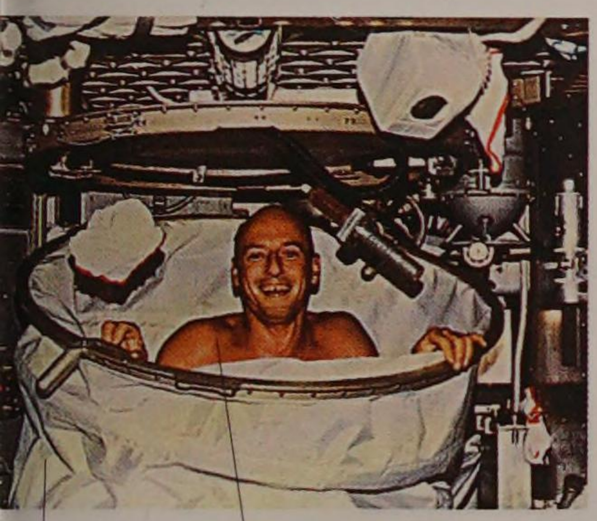
High-flying butterfly

Everything an astronaut needs in space is provided by the space agency, except for any small, personal items. Helen Sharman took this brooch aboard Mir.

Body-washing wipe

Keeping clean

Wet wipes are used to clean astronauts' bodies and the spacecraft. These Russian wipes are designed for space.



Space shower

The first private toilet and shower were on the US space station Skylab. Astronauts on the International Space Station take sponge baths with one cloth for washing and one for rinsing. They wash their hair with rinseless shampoo.

Astronaut Jack Lousma

Water is air-blasted at the astronaut and immediately sucked up

Handle for the stronaut to hold himself down

The toilet seat is lifted for cleaning

Cutaway shows how the waste is collected

Funnel is held close to the astronaut

Hose removes liquid waste

Footrests

aste

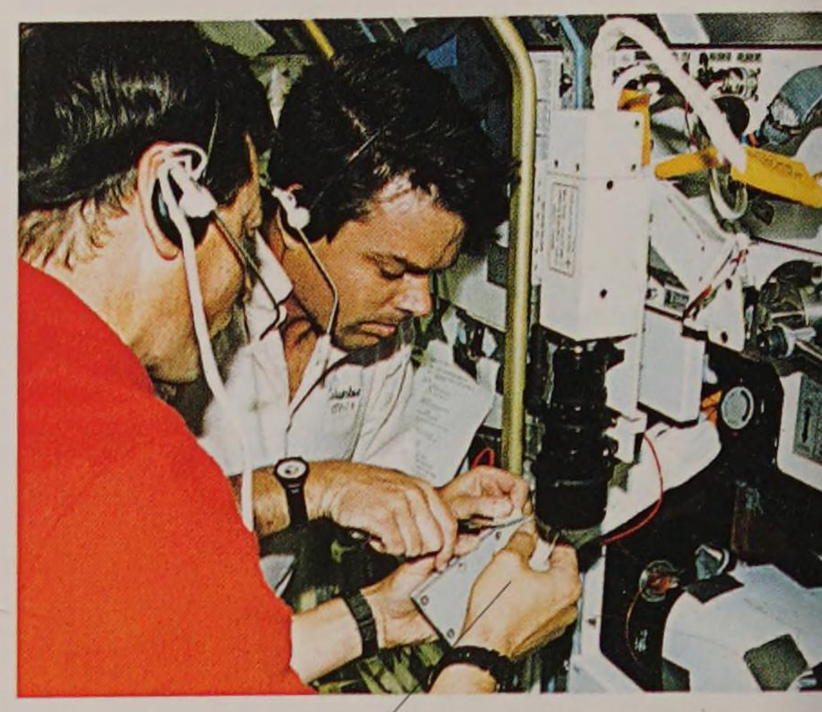
use the toilet, an tronaut fits a funnel to e waste hose, sits down d then holds the funnel se to his body. As the tronaut urinates, the uid is drawn through e hose by a toilet fan. fore discarding solid ste, the toilet bowl is essurized to produce ight seal between the tronaut and the seat.

Model of a space toilet

Space work

Stamp showing an astronaut on extra vehicular activity

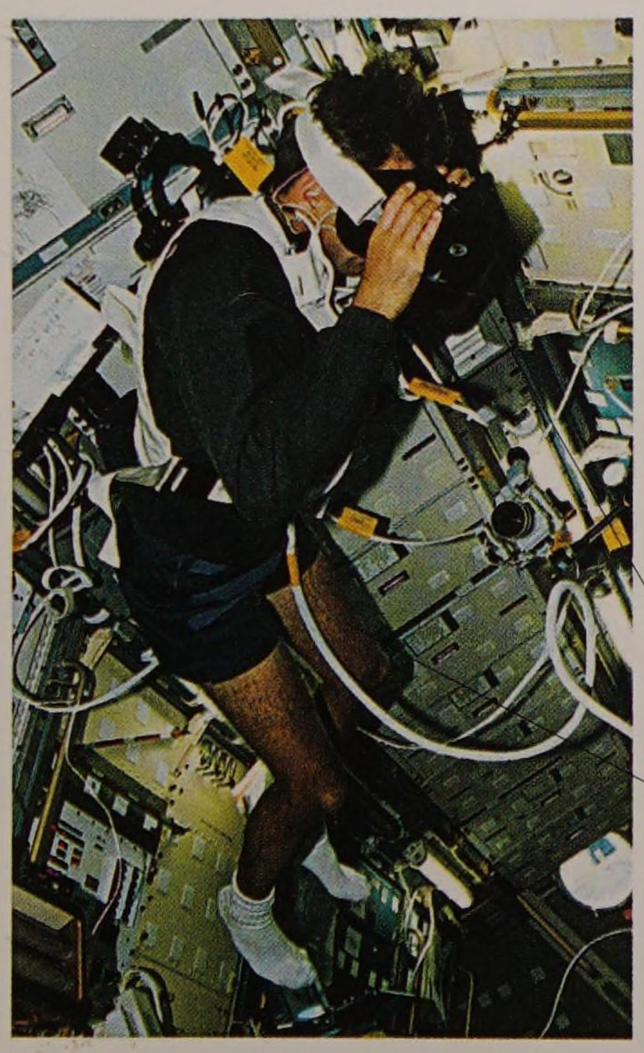
A working day for an astronaut could be spent inside or outside his or her craft. Inside work includes maintenance on the craft, scientific testing, and experimentation. Work outside is called extra vehicular activity (EVA). An astronaut is secured to the craft by a tether, or fixed to a moveable mechanical arm. He or she might deploy satellites or work on the structure of the International Space Station (ISS).



Repair of the Bubble Drop Particle Unit

Running repai

To make repairs to an experiment board the shuttle Columbia, the sar repair procedure was recorded on Ear and the video pictures transmitted the Columbia as a guid



Goggles and headgear

US astronaut Richard Linnehan in Spacelab aboard Columbia

Looking after yourself

For some work, the astronaut is both the scientist and the subject of an investigation. This astronaut's job is to see how the human body copes in space. But without gravity, there is no up and down and this can be disorientating.

Space tasks

Astronauts are assigned tasks on experiments before they leave Earth. They work closely with the scientists and engineers who have designed experiments and stay in touch through the teleprinter and laptop.

Challenger's teleprinter paper in 1985

Preparing samples

Working in a glove box

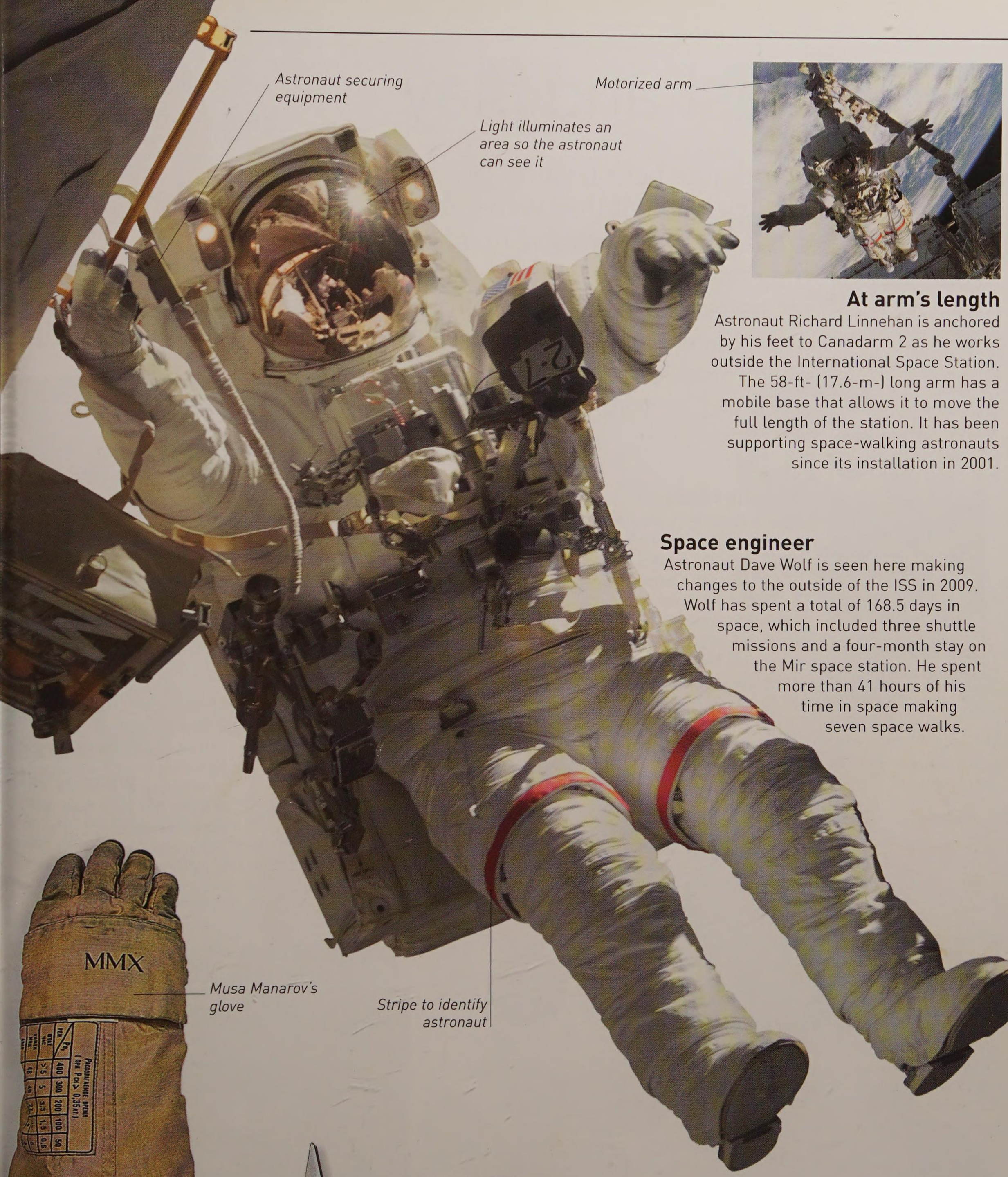
Experiments are conducted in Mir and in Spacelab (right). Here, US astronaut Leroy Chiao (top) places samples in one of the centrifuges on board. American Donald Thomas's hands are in the glove box, a sealed experiment unit.

Securing pins

Sheet cutters

Bolt tightener

Wire cutters



At arm's length

Astronaut Richard Linnehan is anchored by his feet to Canadarm 2 as he works outside the International Space Station. The 58-ft- (17.6-m-) long arm has a mobile base that allows it to move the full length of the station. It has been supporting space-walking astronauts since its installation in 2001.

Space engineer

Astronaut Dave Wolf is seen here making changes to the outside of the ISS in 2009. Wolf has spent a total of 168.5 days in space, which included three shuttle missions and a four-month stay on the Mir space station. He spent more than 41 hours of his time in space making seven space walks.

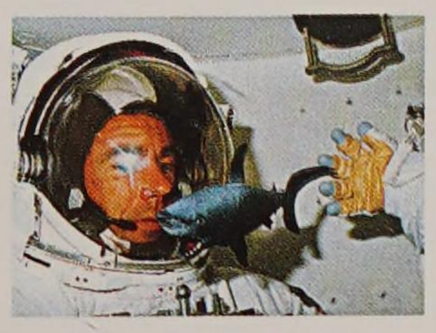
and in glove

ace gloves are necessary to otect astronauts working on A against the cold. However, y must also allow astronauts grip their tools. Gloves can en leave fingers cold.

Tools of the trade

An astronaut's tool kit includes tools for every imaginable job, from an electric wrench used in satellite repair, to a soft copper brush for cleaning dust from the outside of porthole windows.

Rest and play



US astronaut Bill Lenoir watching his floating rubber shark

Astronauts have leisure time in space just as they would if they were down on Earth. When the day's work is finished, they may read, listen to music, or watch the world far below them. When the first astronauts went into space, they had every moment of their time accounted for and ground control was always listening in. Today, astronauts have time to unwind.

Writing home

Laptop computers are used by astronauts to stay in touch with family and friends. Mir astronauts stamped and dated their letters and handed them over when back on Earth. This French stamp for Earth-use celebrates communications.

Gravity stops an eighth magnetic marble joining the chain

Jacks float in mid-air without gravity

In space, more weightless marbles could be added

Stay still!

In space, the jacks are released in midair but always drift apart. The ball is thrown at a wall and caught on its return journey.

Yo-yos work in any direction without gravi

Mouthpiece is sealed between sips

Snack time

Astronauts have snacks including dried fruit, nuts, crumb-free granola bars, and hot or cold drinks. This coke can requires a special mouthpiece so the drink doesn't flow out freely.

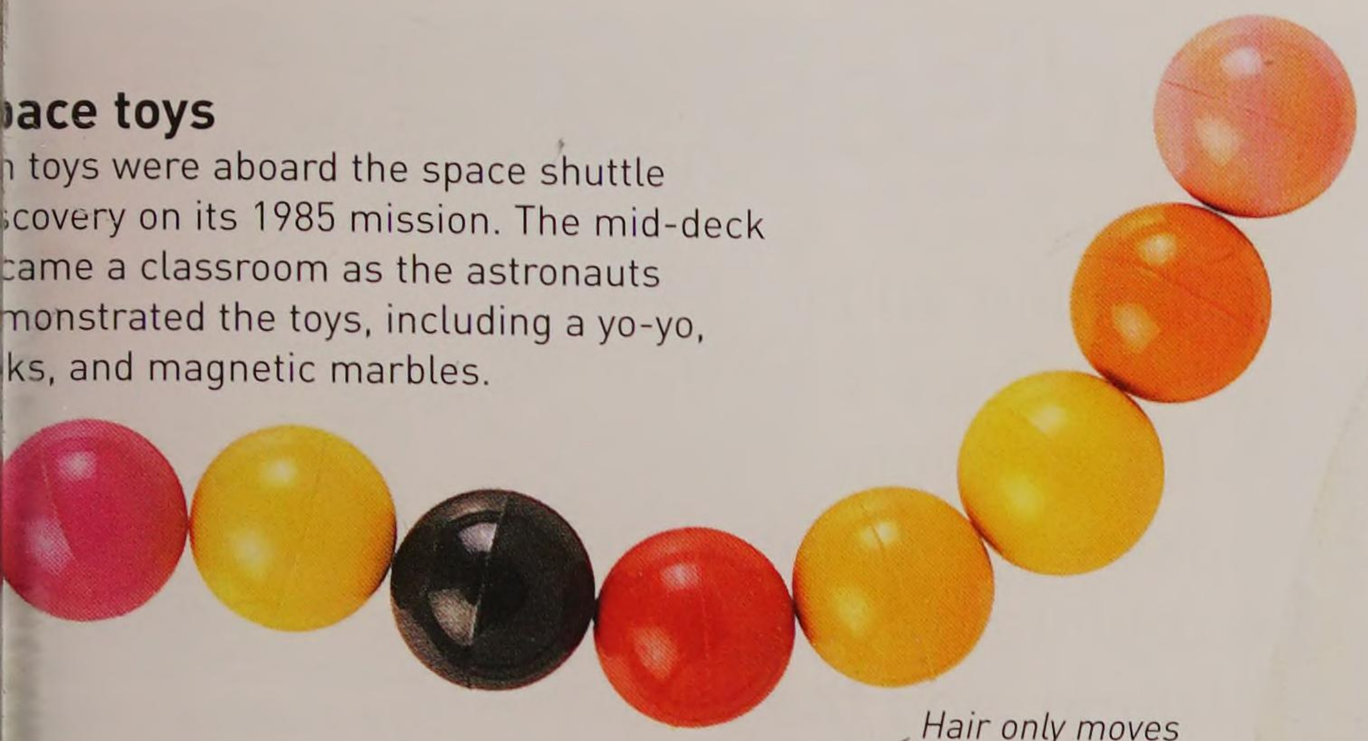
Astronauts must adap their finger technique as the guitar floats

Cosmic chords

Listening to or making music is a popular pastime. Canadian astronaut Chris Hadfield (above) strums a guit as he floats in the ISS. Other instruments onboard includ a flute, saxaphone, keyboard, and an Australian didgerid

ace toys

n toys were aboard the space shuttle scovery on its 1985 mission. The mid-deck came a classroom as the astronauts monstrated the toys, including a yo-yo, ks, and magnetic marbles.



Hair only moves if pushed

American Susan Helms

Hair-raising

Washing clothes and hair are not top priorities in space. Clothes are bagged and brought home dirty. Hair washing can be avoided if the trip is short. Dirt can be wiped away with wet-wipes.

Wubbo Ockels on board the shuttle Challenger

Inflatable ring supports astronaut

Space photographer

Digital cameras and camcorders are on board every spacecraft. Astronauts take official photos and fun shots. Here, American Karl Henize photographs through the window of the Challenger shuttle.

Wool slippers provide warmth

1980s sleeping bag

Good night, sleep tight

Astronaut sleeping bags are attached to the sides of the spacecraft, or a sound-suppression blanket with weightlessness restraints are used in a bunk bed. This sleeping bag was used in the 1980s aboard the space shuttle and Mir.

The space shuttle was launched next to a wildlife refuge in Florida. Space technicians regularly checked in on the birds nesting there.

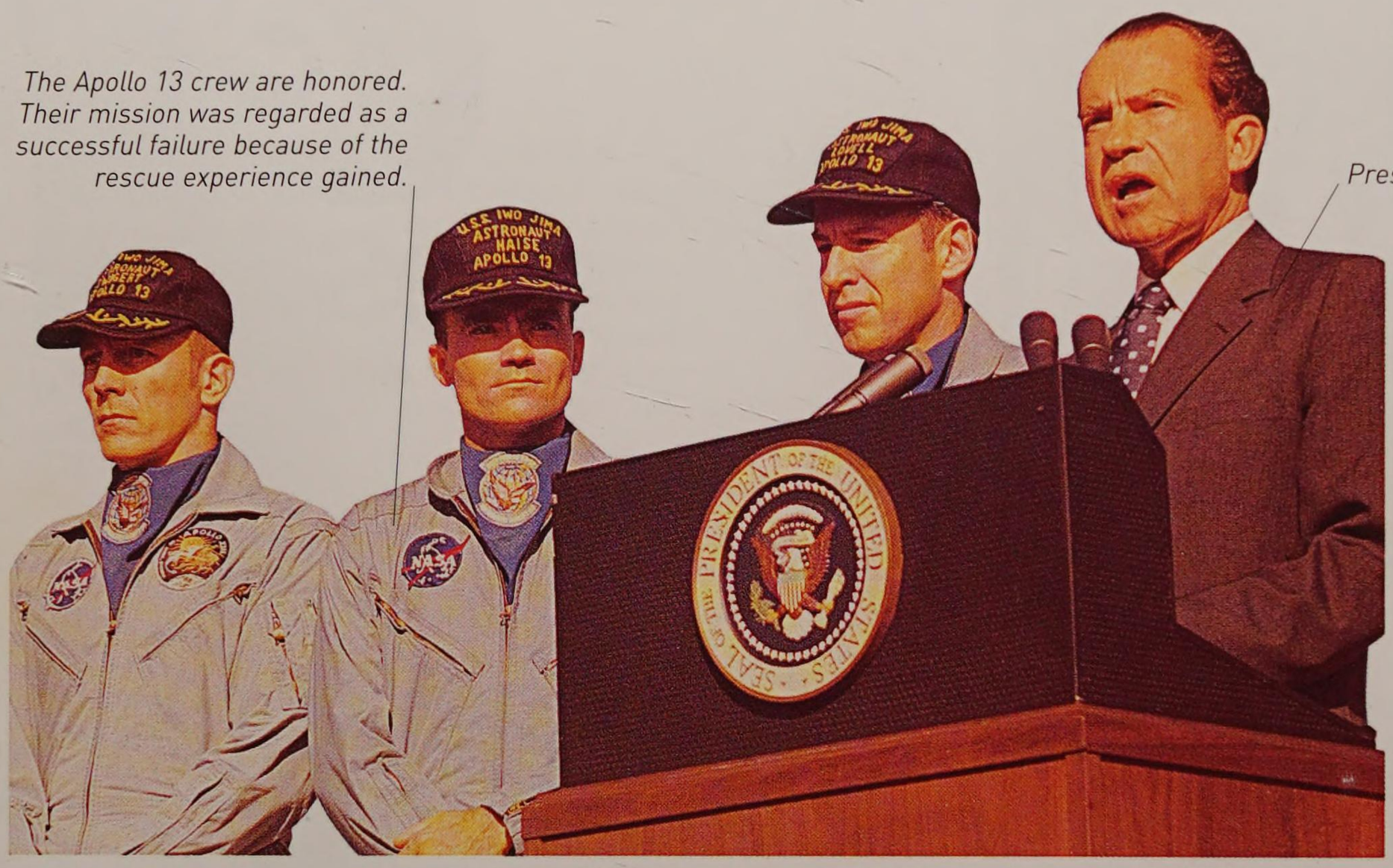
Danger and disaster

Great care is taken in the planning and preparation of a space mission. Once a rocket leaves the ground, there is little anyone can do if things go wrong. Mistakes and problems range from an astronaut's cold delaying a flight, through to whole projects failing, and the loss of life. But, luckily, big disasters are rare.

Fatal flight
Vladimir Komarov was t first human to be killed space flight. After a da in space, he descende to Earth on April 24, 196 His parachute on Soyuz failed, and the craft plunged to Earth.

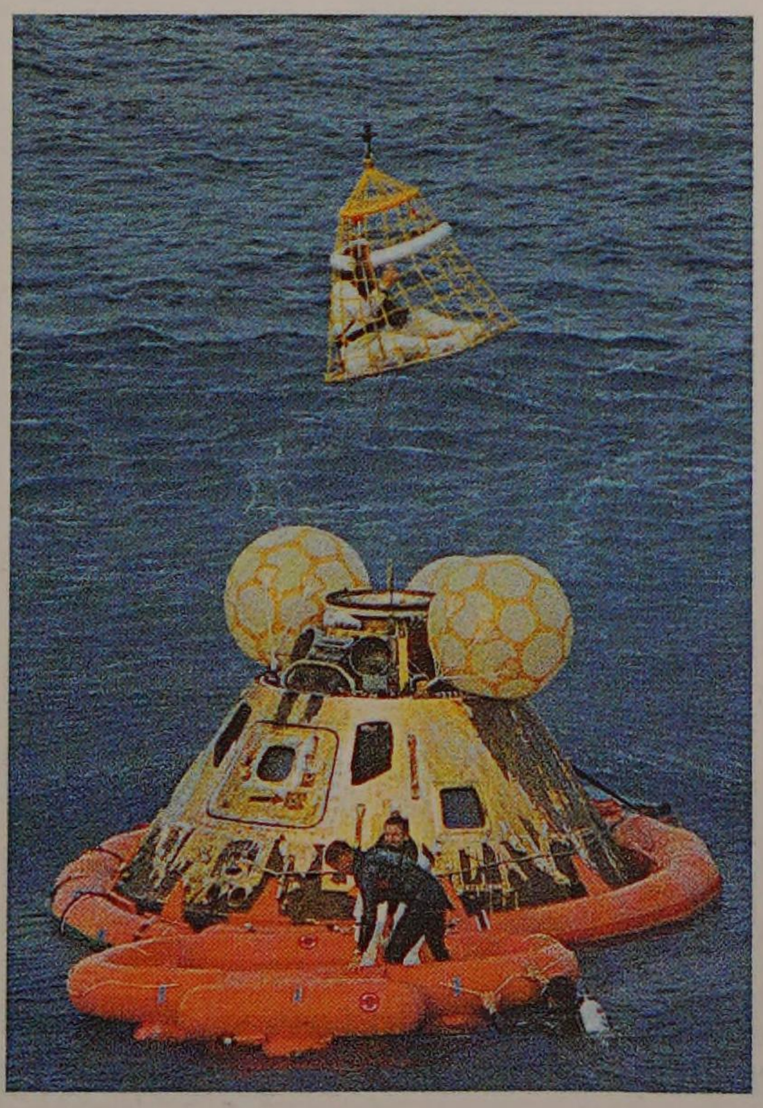
The Apollo 13 crew are honored. Their mission was regarded as a successful failure because of the rescue experience gained.

President Nixon



John Swigert Fred Haise James Lovell Richard Nixon

Mission abort
On April 13, 1970, Apollo 13's journey to the Moon was interrupted when a ruptured oxygen tank caused an explosion that damaged power and life-support systems on board. The planned lunar landing was abandoned to get the three-man crew home safely.



Engine swap
The explosion aboard Apollo 13 was in the service module and put its engine out of action. The astronauts instead used the engine from the lunar module to return back to Earth.

Flash fire
Astronauts Virgil Grissom, Edward White, and Roger Chaffee perished when they could not escape a fire in Apollo 1's command module during a practice launch in 1967.

Heat damage on the command module

Urns holding the astronauts' remains

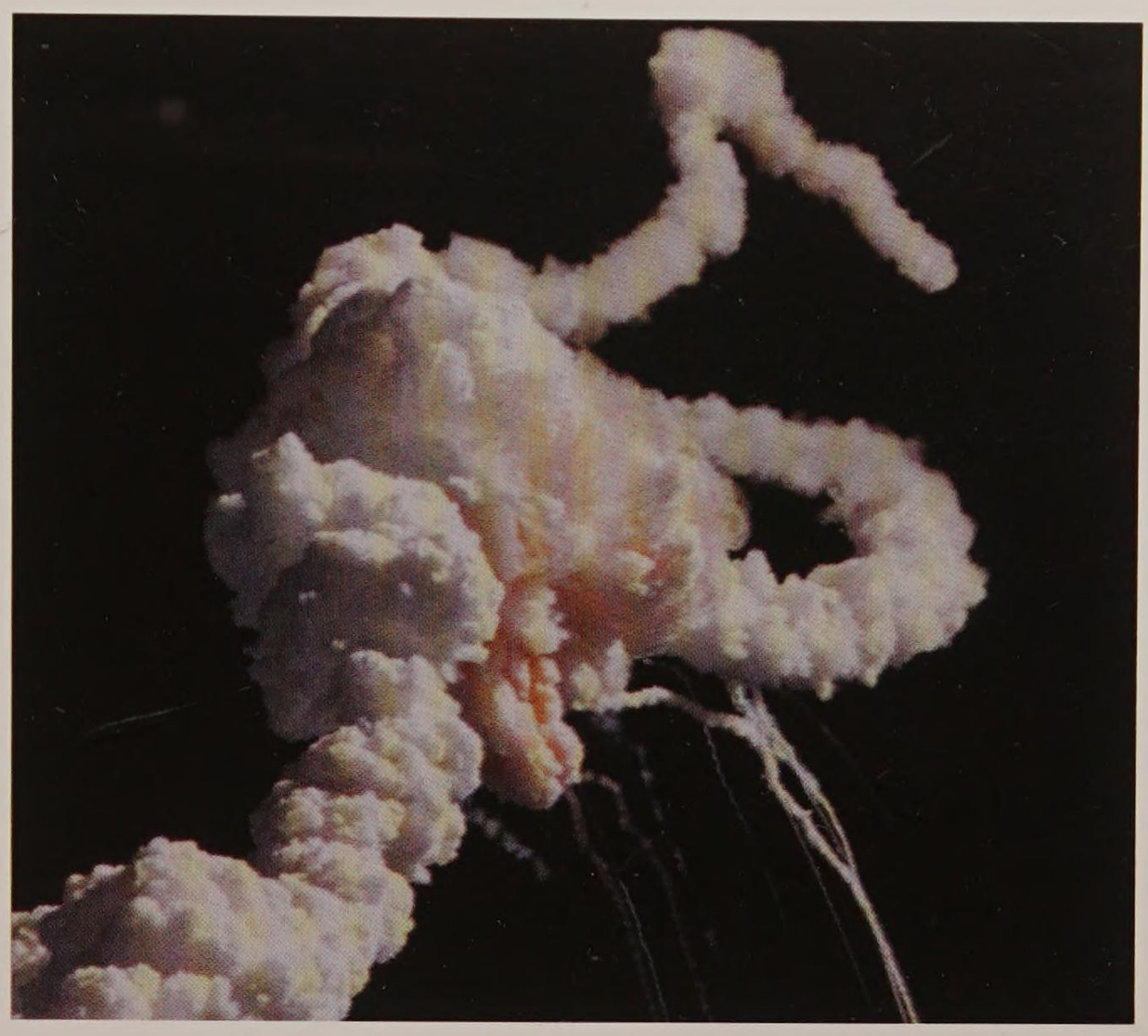
Return from space
Astronauts Georgi Dobrovolsky, Vladisla Volkov, and Viktor Patsayev died on thei return journey from Salyut 1 space stati in 1971. All three suffocated after air escaped from their capsule.

Astronauts practice a launch pad emergency exit

Each basket can carry three crew members safely to the ground

scape route

nergency procedures allow astronauts to t away from their craft quickly. For shuttle tronauts, the escape route before countdown s via a steel-wire basket. It took 35 seconds get to the ground, practiced here.



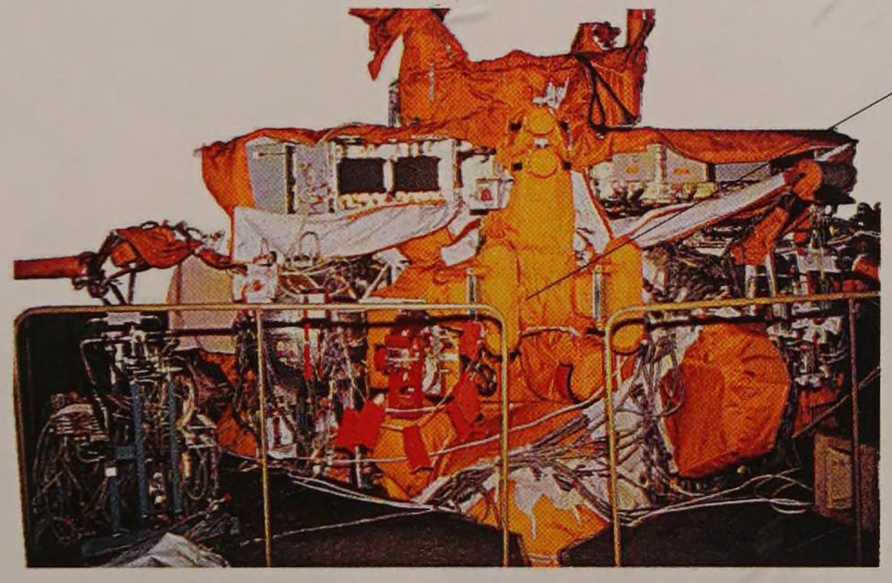
Space shuttle tragedies

Launch-pad preparation and liftoff are dangerous parts of a mission. In 1986, the space shuttle Challenger exploded 73 seconds after liftoff. All seven of the crew were killed. In 2003, the Columbia shuttle disintegrated as it returned to Earth.

Lost in space

In February 1996, astronauts were putting a satellite into space when the 12.8 mile (20.6 km) tether that connected it to the space shuttle Columbia snapped. The $442 million satellite had to be given up for lost.

With only 33 ft (10 m) to go, the satellite tether broke



Mars-96 at the Lavochkin Scientific-Industrial Association

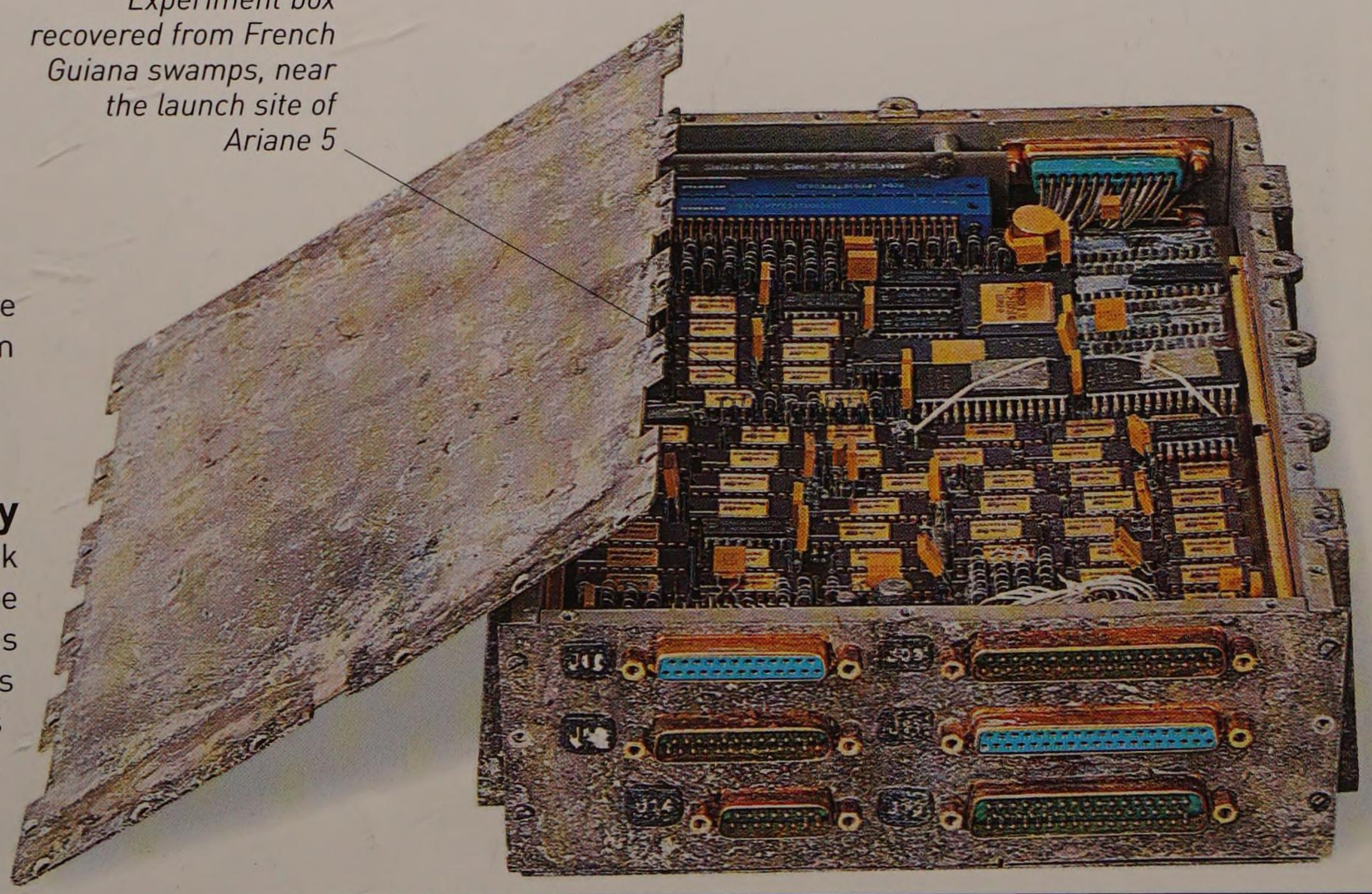
Mars-96

Contact with the Russian space probe Mars-96 was lost half an hour after its launch in 1996. Its boosters had failed to lift Mars-96 out of Earth's orbit.

Fuel pecker

A yellow-shafted flicker woodpecker delayed the launch of space shuttle Discovery in 1995. The bird had pecked more than 75 holes in the fuel tank's insulating foam. Plastic owls to scare off birds were used to prevent the problem from occurring again.

Experiment box recovered from French Guiana swamps, near the launch site of Ariane 5



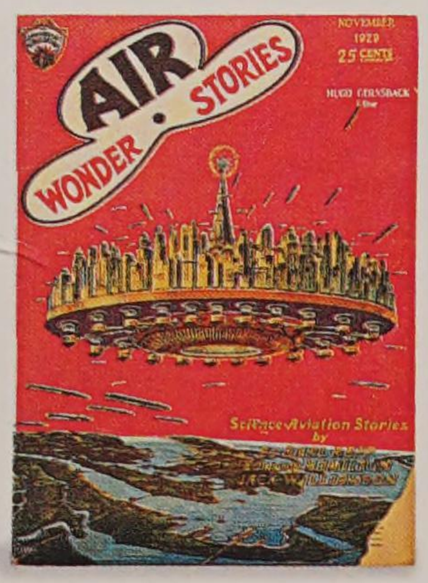
Lost property

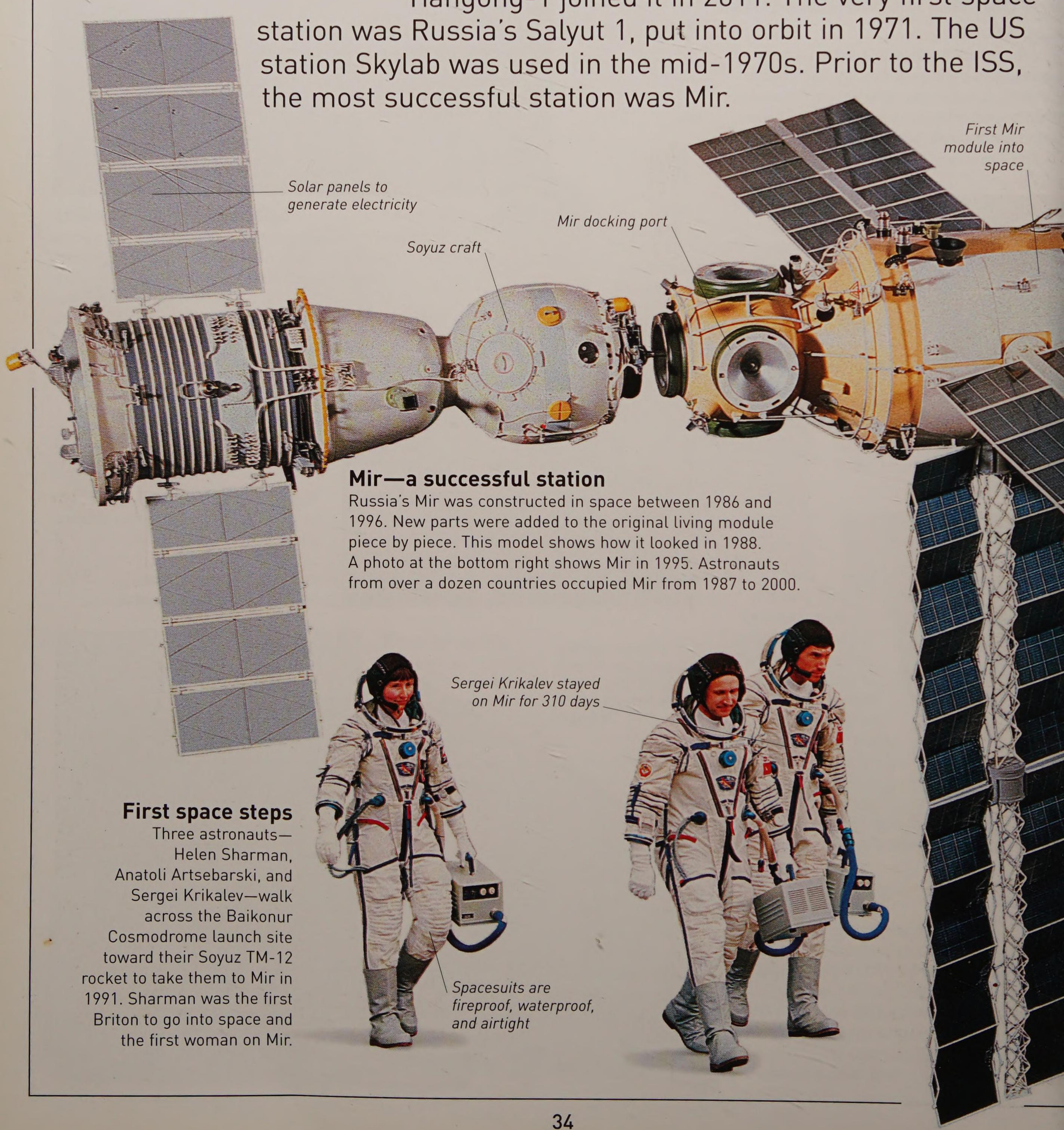
The failure of Mars-96 was a setback for the Russian space program. The probe was scheduled to land four probes on Mars in 1997. The loss of experiments on this probe came only five months after the destruction of experiments on the European Space Agency rocket Ariane 5.

Space stations

About 240 miles (390 km) above the Earth, two space stations orbit our planet 15 times a day. The International Space Station, or ISS, is the largest space station ever built. China's smaller Tiangong-1 joined it in 2011. The very first space station was Russia's Salyut 1, put into orbit in 1971. The US station Skylab was used in the mid-1970s. Prior to the ISS, the most successful station was Mir.

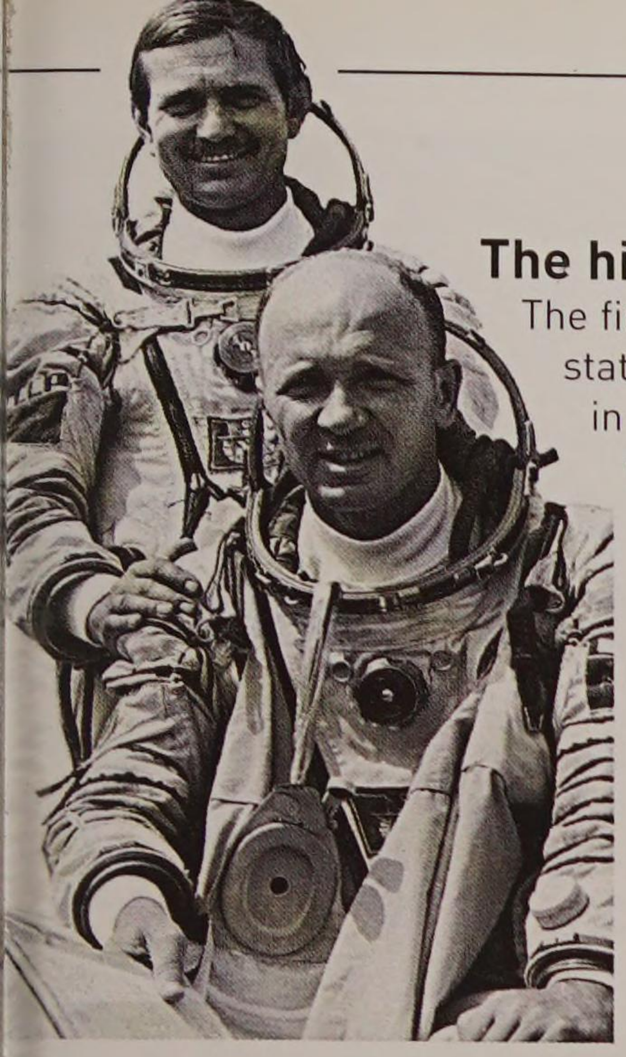
Space city
A city in the sky is not a new idea. The city of Laputa, in *Gulliver's Travels*, lifts off from the ground. This 1929 comic shows a larger airborne city.





Mir—a successful station
Russia's Mir was constructed in space between 1986 and 1996. New parts were added to the original living module piece by piece. This model shows how it looked in 1988. A photo at the bottom right shows Mir in 1995. Astronauts from over a dozen countries occupied Mir from 1987 to 2000.

First space steps
Three astronauts—Helen Sharman, Anatoli Artsebarski, and Sergei Krikalev—walk across the Baikonur Cosmodrome launch site toward their Soyuz TM-12 rocket to take them to Mir in 1991. Sharman was the first Briton to go into space and the first woman on Mir.



The high life

The final Salyut space station was launched in 1982. Salyut 7 was in orbit, about 200 miles (320 km) above Earth, until 1991. The first crew members were Anatoly Berezovoi (top) and Valentin Lebedev (bottom).

Sergei Avdeev stayed on Mir for over five months

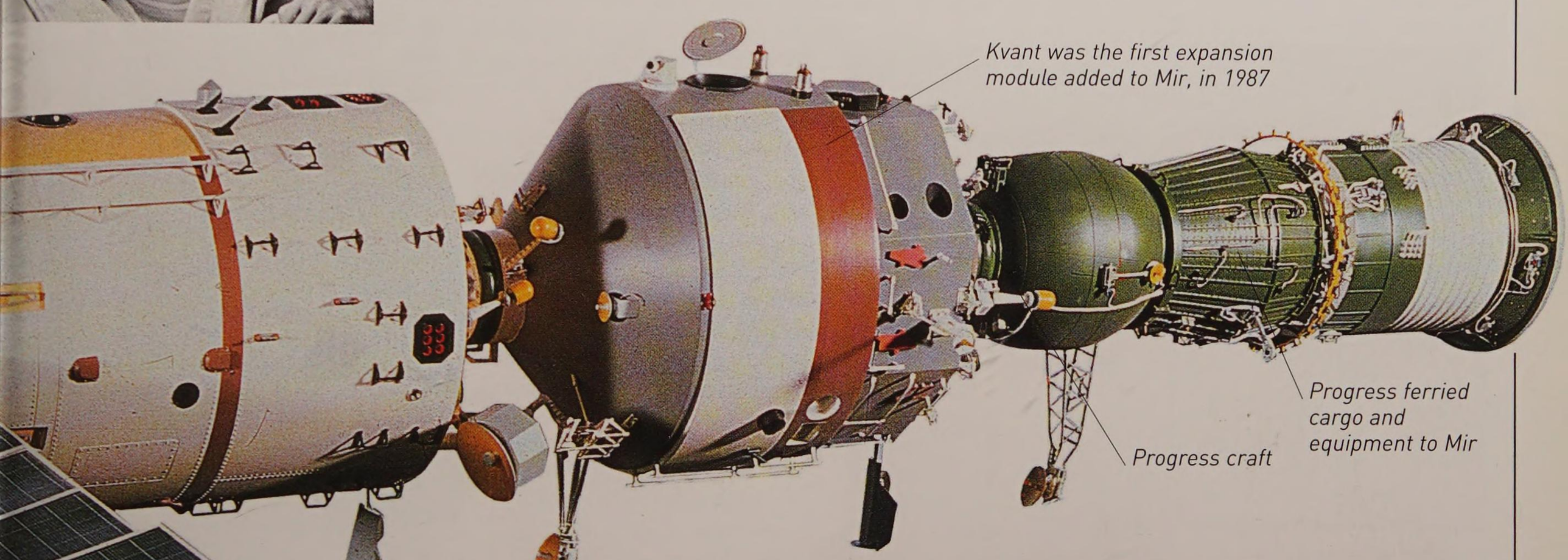
Mir astronaut signatures

Postcards from space

Cards like this one went through Mir's own post office. The office's unique postmark was stamped by hand. The Mir crew stamped around 1,000 envelopes for collectors.

Inside Mir

The inside of Mir was similar in size and shape to a train car. Inside was equipment for experiments and the operation of the space station.



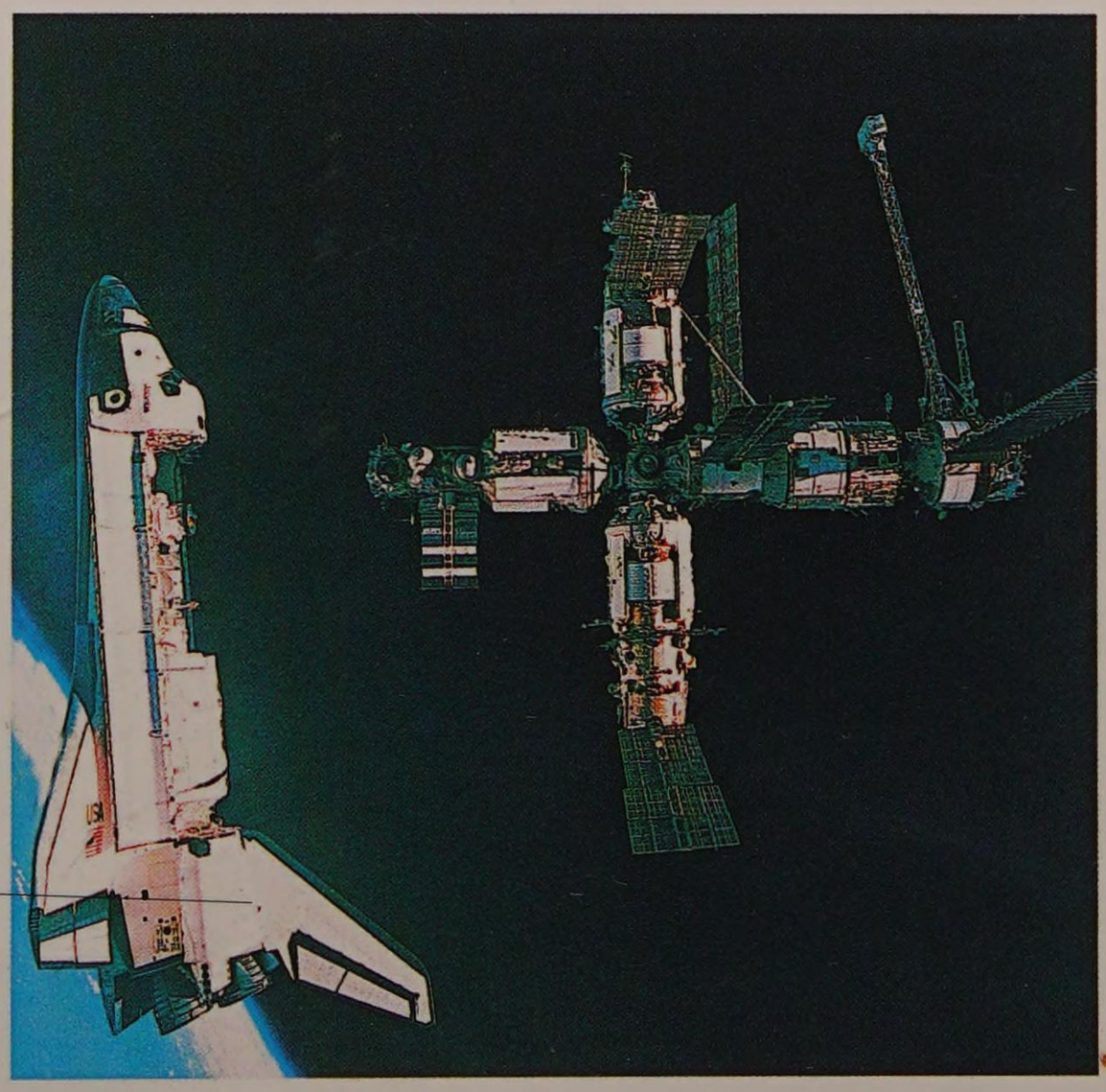
Kvant was the first expansion module added to Mir, in 1987

Progress craft

Progress ferried cargo and equipment to Mir

Space union

In 1995, the US space shuttle Atlantis made its first docking with Russia's Mir. At the time, they formed the largest craft ever to have orbited Earth.



Photograph of Atlantis moving away from Mir

Hitching a ride

Anatoly Solovyev and Nikolai Budarin were taken to Mir aboard Atlantis. Once the orbiter had docked with Mir, the hatches on each side were opened and the astronauts passed through.

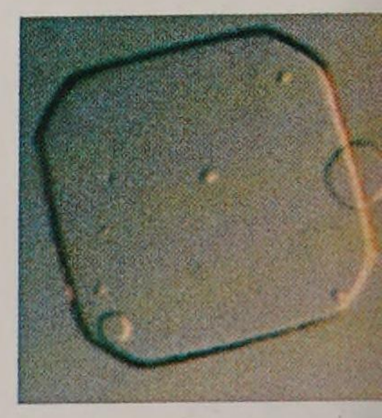
Months on Mir

Atlantis and Mir were docked together for about 100 hours as they orbited Earth in 1995. On board were the astronauts who had arrived on Atlantis, and three other astronauts who had spent over three months on board Mir.

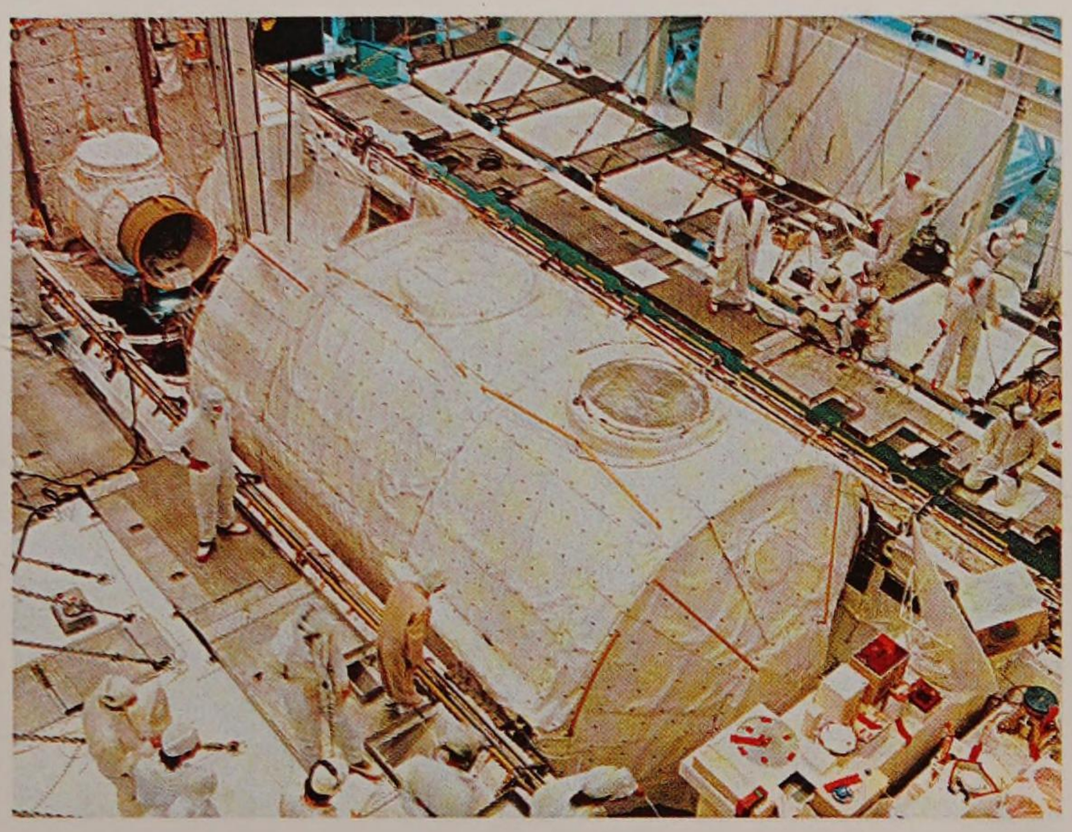
Patch for Spacelab 2—1985

Science in space

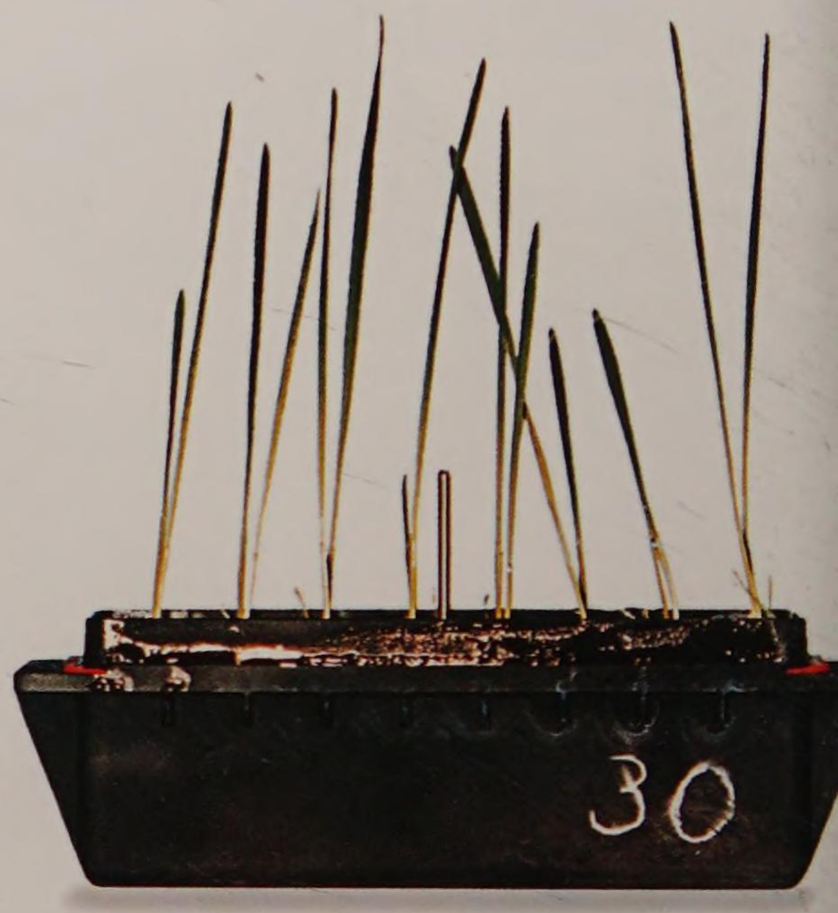
Astronauts monitor, control, and perform experiments inside and outside their craft as they orbit Earth. The experiments investigate how living things, such as astronauts, insects, and plants, cope in space. They also examine chemical processes and the behavior of materials. The knowledge acquired is used for planning the future of space.



Crystal
This crystal of human-body plasma protein was grown in space. It is larger than a crystal grown on Earth.



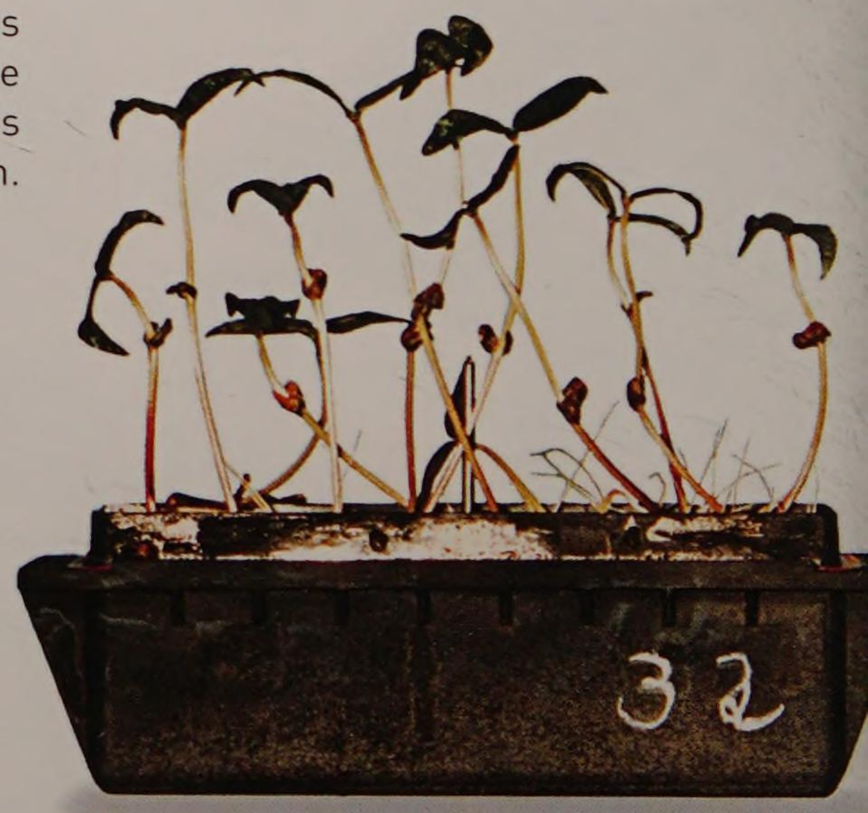
Spacelab
A laboratory designed for space, Spacelab, flew in the payload bay of the space shuttle, pictured here. Astronauts worked in Spacelab's pressurized cabin, and U-shaped pallets on the outside of the cabin held instruments for direct exposure to space.



Oat seedlings

Growing food
A plant-growth unit was used in 1982 to test how weightlessness affects plants. The oat and mung bean seedlings grew to look much the same as seedlings grown on Earth.

Oat seedlings in an experiment box



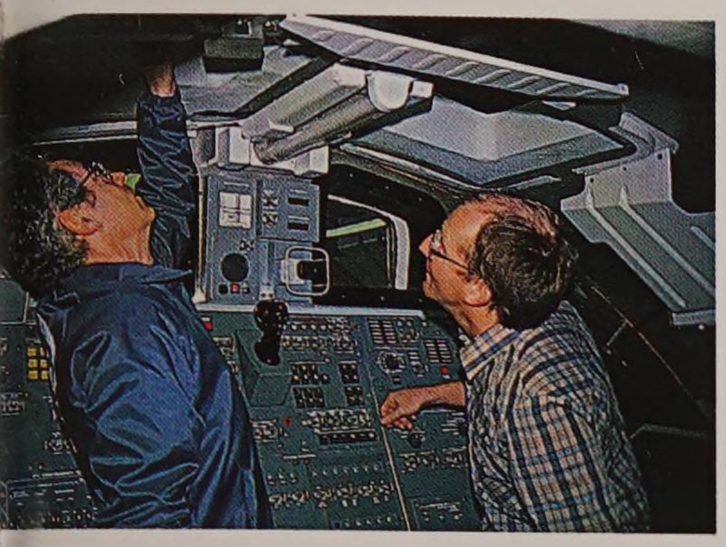
Mung bean seedlings

Seeds and eggs
In 1991, astronaut Roberta Bondar studied the effects of weightlessness on lentil and oat seedlings, and on shrimp and fruitfly eggs.

Baby boom
The first Earth creature to be born in space emerged from its shell on March 22, 1990. The quail chick was the result of an experiment aboard Mir. Forty-eight quails' eggs had been placed inside a special incubator with ventilation, feeding, heating, and storage systems attached. After a 17-day wait, six chicks broke free from their eggs. It marked a key moment in research into space reproduction.

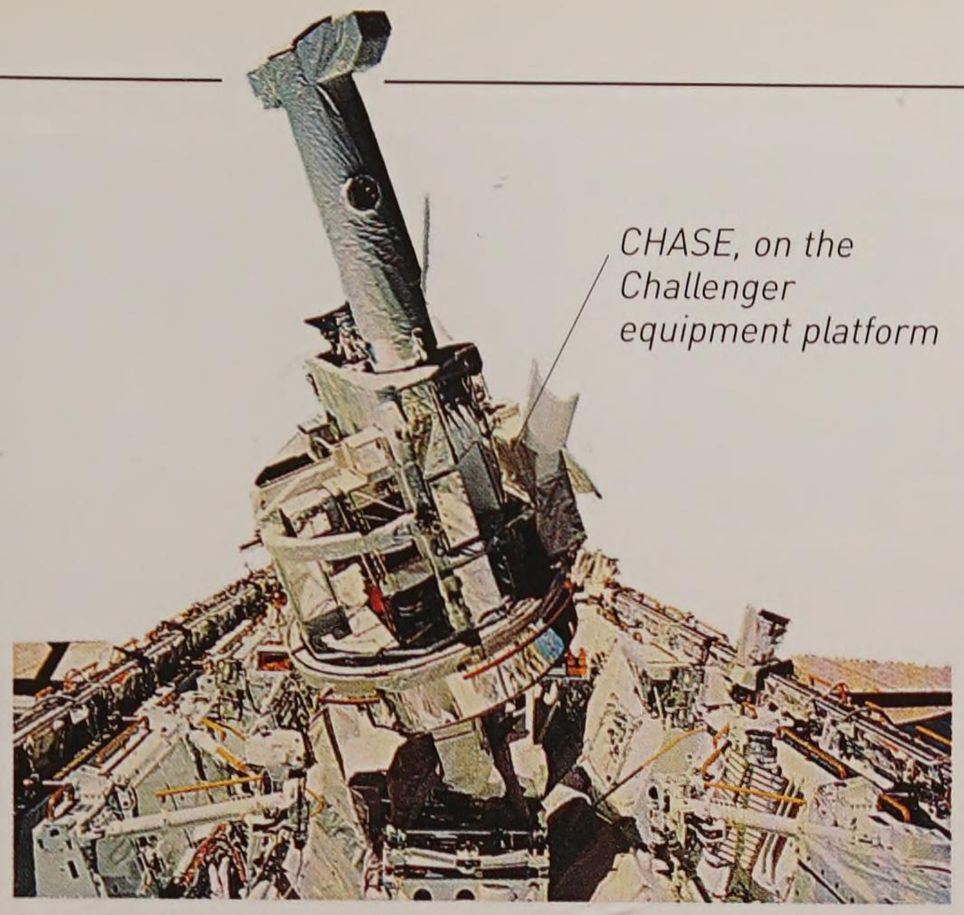
Cracking Quail's egg

Chick emerges



orking together

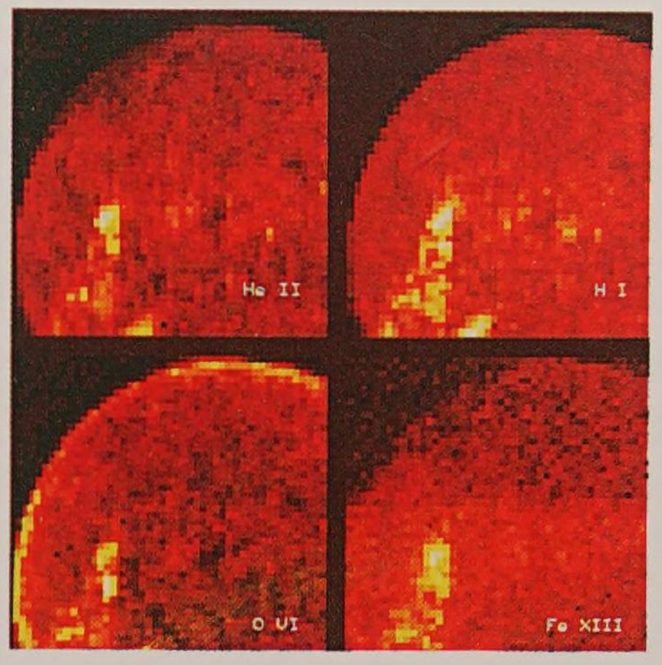
ronauts often perform experiments in ace for Earth-based scientists. Here, entist John Parkinson (right) gives ronaut Karl Henize telescope lessons.



CHASE, on the Challenger equipment platform

CHASE—a telescope in space

In 1985, a telescope called the Coronal Helium Abundance Spacelab Experiment (CHASE) flew into space aboard the space shuttle Challenger.



CHASE solar images

CHASE made these images of the Sun. They are in false color to bring out details. The images are of the Sun's outer gas layer, the corona. Each one depicts a different height within the corona.

Footgrips to stay steady

Torso Rotation Experiment

Richard Linnehan, an American, tests his muscle response

Weightless work

The French stronaut Jean-Jacques Favier wears the Torso Rotation Experiment, which studies the effects of weightlessness on the body. The Columbia crew members were also tested for bone tissue loss and muscle performance.

Candle flames

Gravity and airflow influence the spread of an Earth fire, but what affects a space fire? Tests have shown that space flames form a sphere rather than the pointed shape they have on Earth (left).

Arabella in her web

Arabella the spider

One space science experiment investigated if two spiders, Anita and Arabella, could spin webs in weightless conditions. Their first attempts were not perfect, but after a while the spiders built well-organized webs.

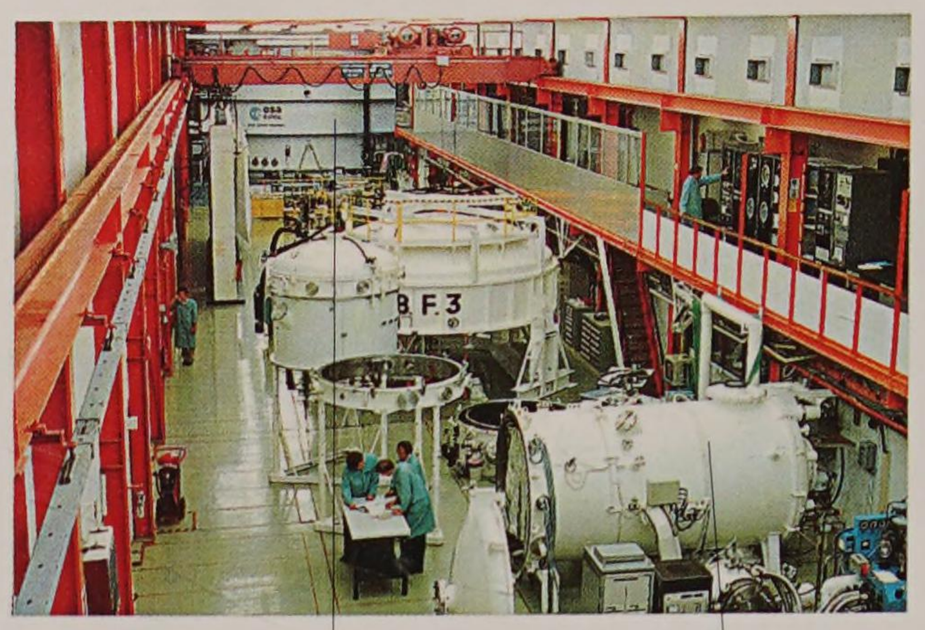
Chick squeezes out of broken egg

Eggshell falls away as chick hatches

Quail chick stands up

Equipment

Any equipment sent into space undergoes lengthy tests before liftoff. Prototypes of each part of a space probe or satellite are built and tested before the actual flight parts are made. About a year before launch, these parts are assembled. The whole craft is then tested to ensure it is spaceworthy. It must be able to withstand the stress of the launch and the environment in space.

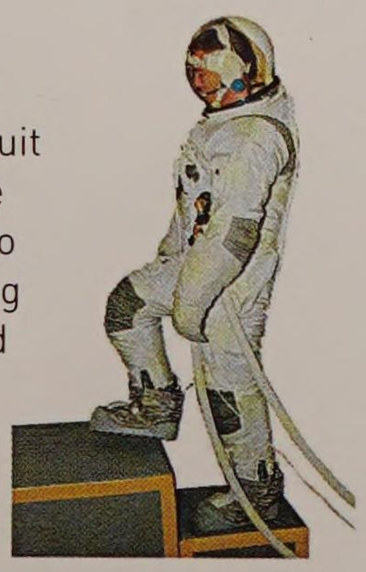


The Large Space Simulator (LSS)

Facilities for equipment testing

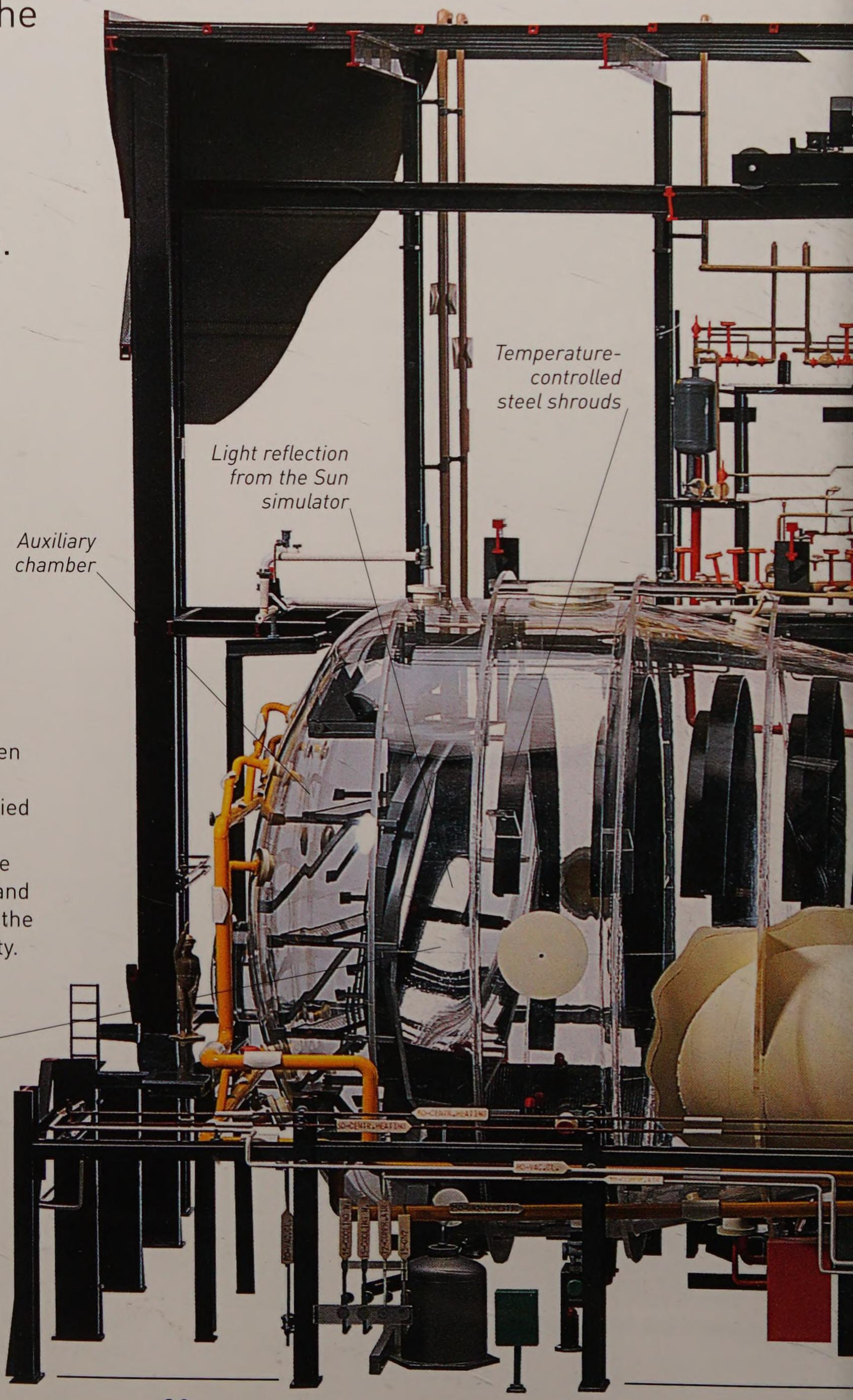
Craft tests
At its Netherlands space center, the European Space Agency (ESA) analyze the behavior of space probes and satellites to assess how spaceworthy th craft are. The tests take place in controlle clean conditions.

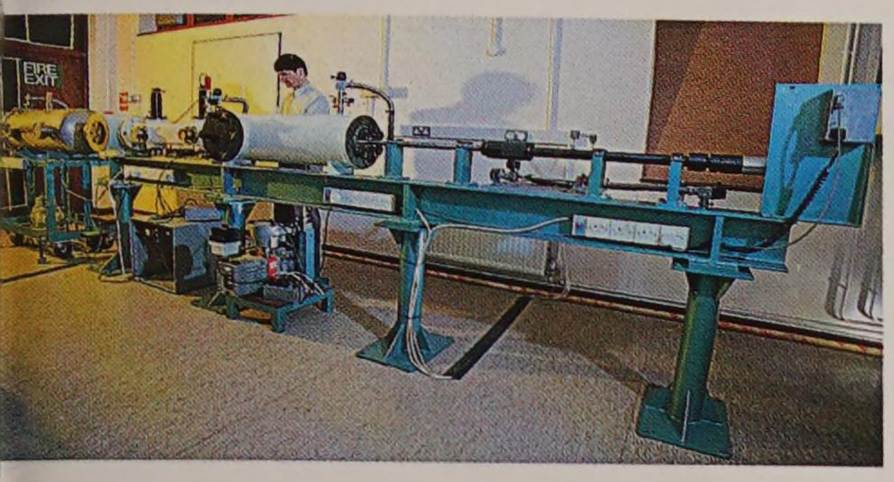
Human tests
Here, American John Bull tests a new Apollo spacesuit in 1968. Bull later became sick and never made it into space. Astronauts traveling into space are often tested to make sure they are in top condition.



Adapting to space
Modern astronauts are often tested for endurance and adaptability. Tests are carried out on other humans for comparison. Volunteers are strapped down, wired up, and swung around to simulate the return from space to gravity.

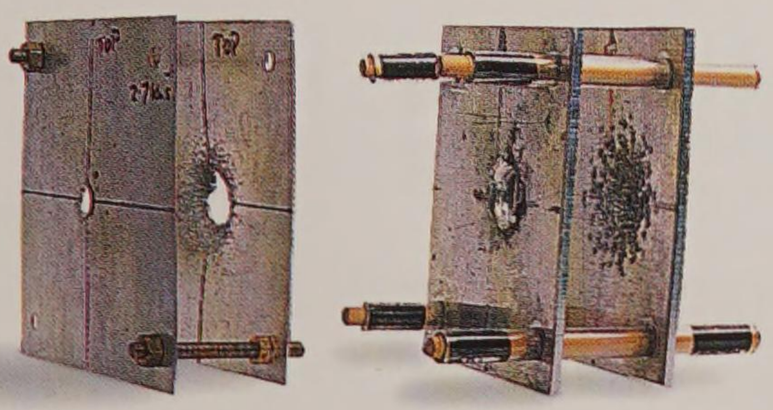
Large Space Simulator
The conditions a craft will encounter in space are simulated by special test equipment. The European Space Agency (ESA) uses the Large Space Simulator (LSS) to test its space probes and satellites. It works by re-creating the vacuum, heat, and solar radiation conditions of space. This is a model of the LSS that allows you to see inside.





as gun

acecraft need protection against space rticles, which can produce holes when they hit e craft. Scientists in Canterbury, UK, use a gas n to assess the damage of such particles.

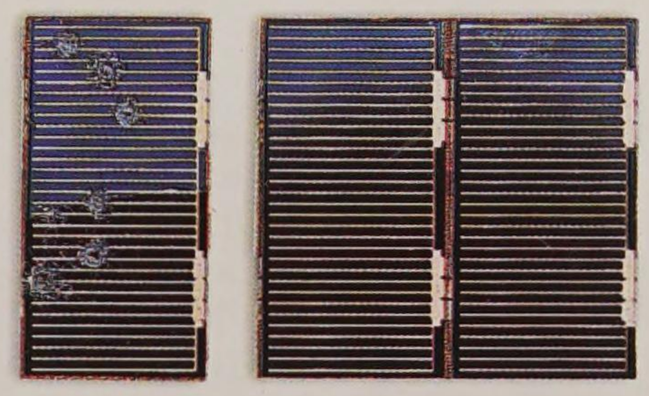


Thin metal test

Thick metal test

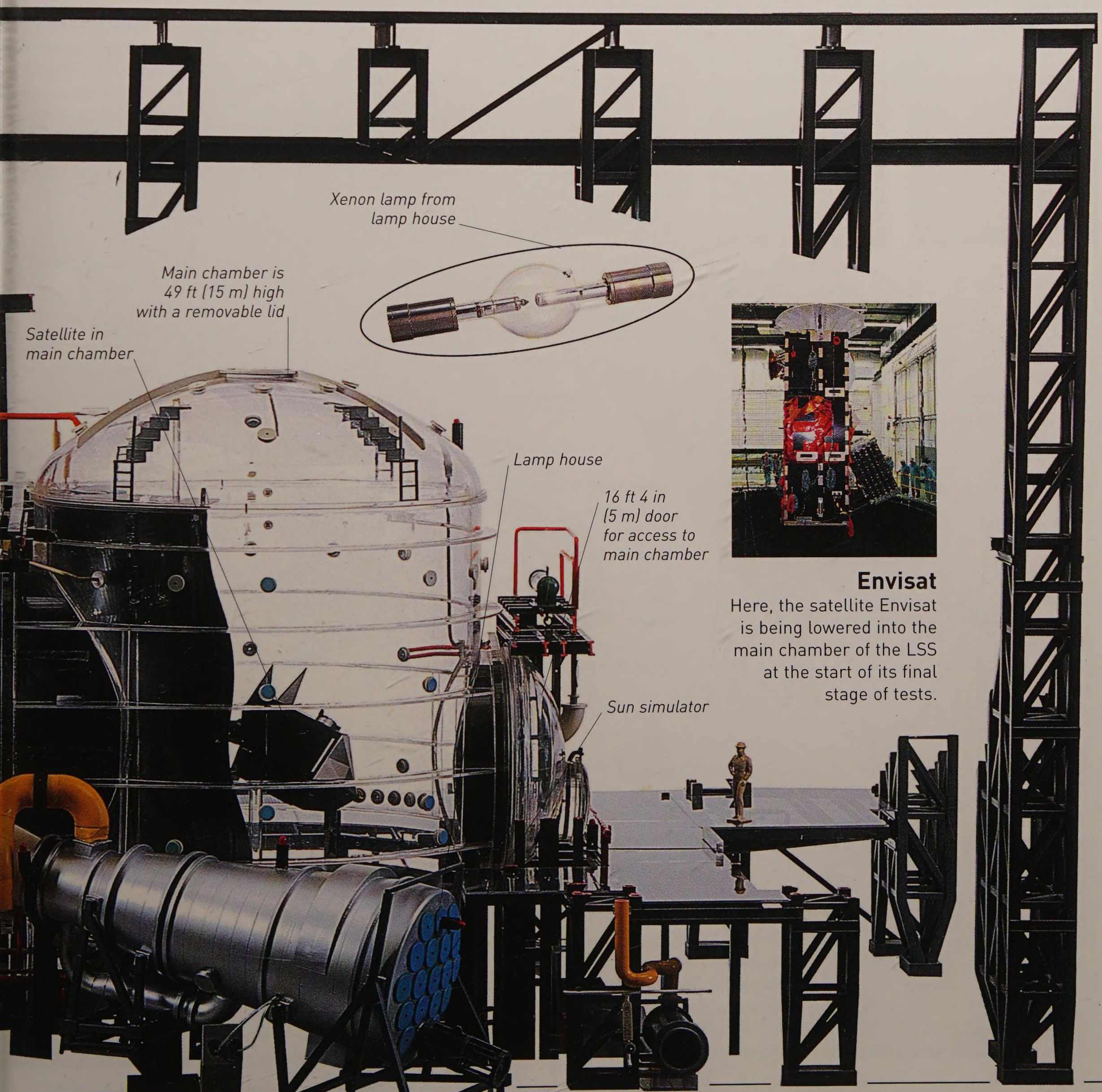
Bumper shield

Scientists test different thicknesses of metal to minimize the damage made to space probes by dust particles. A double layer shield helps reduce damage.



Solar panels

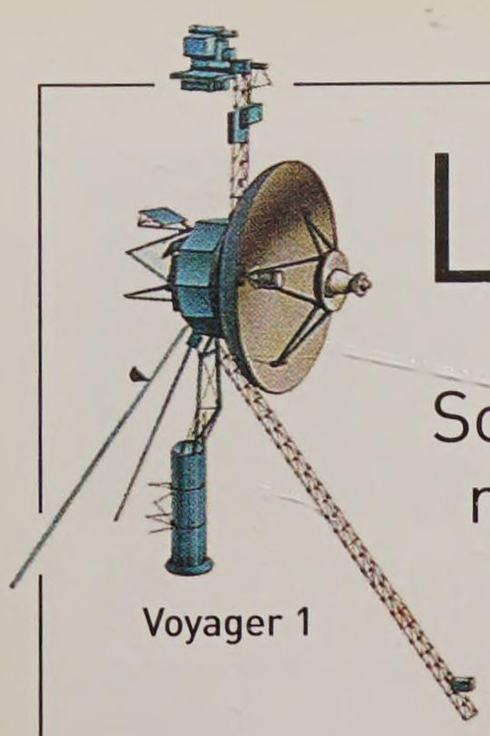
The effects of space dust are shown on these solar panels. The panels on the right have not been used, while the panel on the left has dents caused by space particles.



Envisat

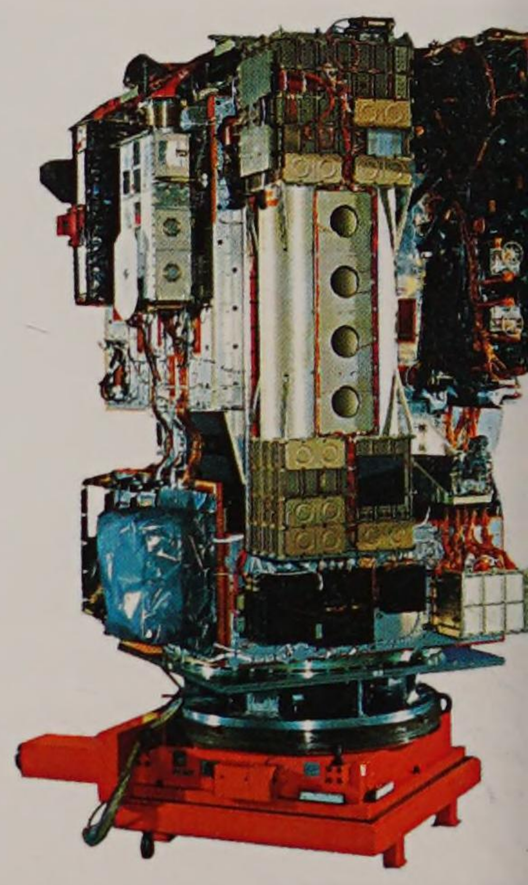
Here, the satellite Envisat is being lowered into the main chamber of the LSS at the start of its final stage of tests.

Lonely explorers

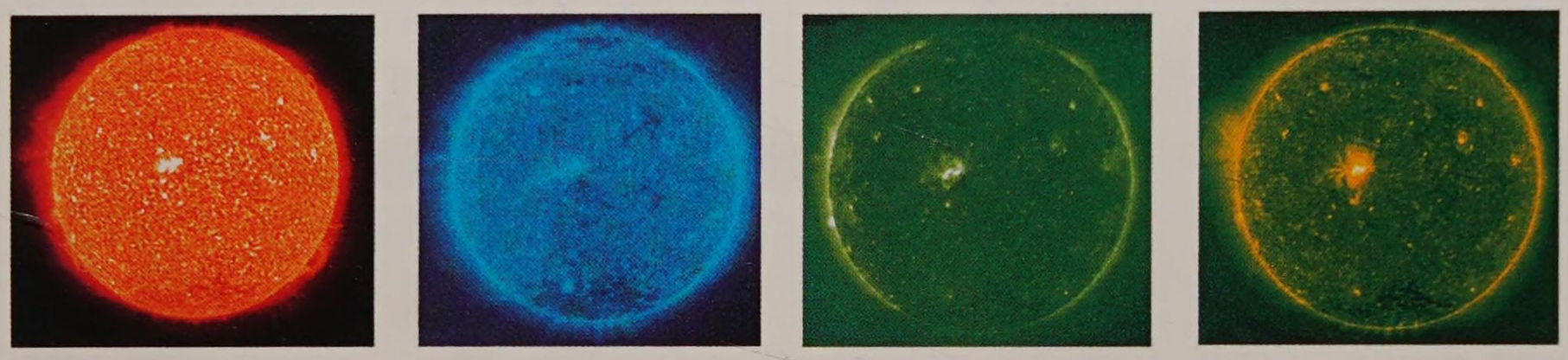


Voyager 1

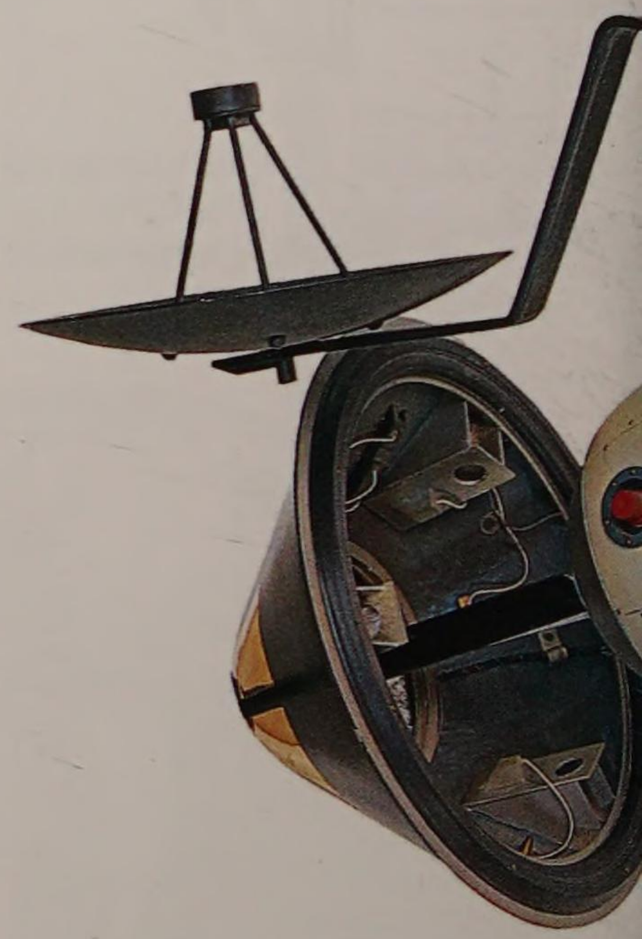
Scientists sometimes explore space using robotic spacecraft, called probes. About the size of family cars, probes contain scientific experiments, a power supply, small thruster rockets, and a means for sending data back to Earth. A probe may fly by its target, or orbit it, or land on it. Probes have investigated the Sun and all eight solar system planets.

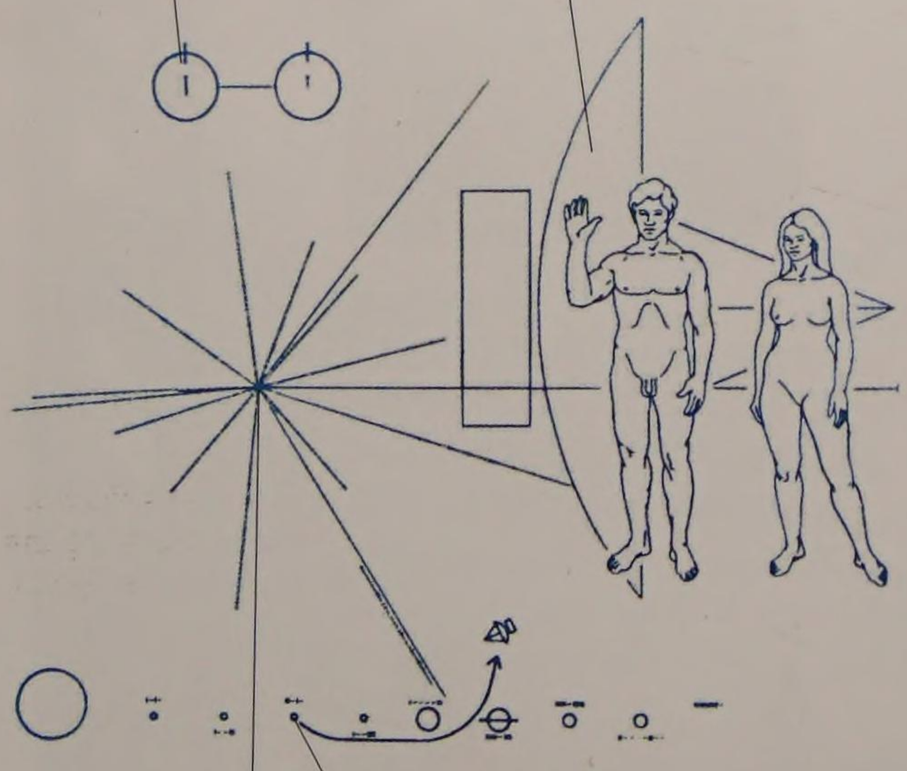


SOHO spacecraft
The Solar and Heliospheric Observatory (SOHO) is a spacecraft that constantly studies the Sun. It started its work in 1996.

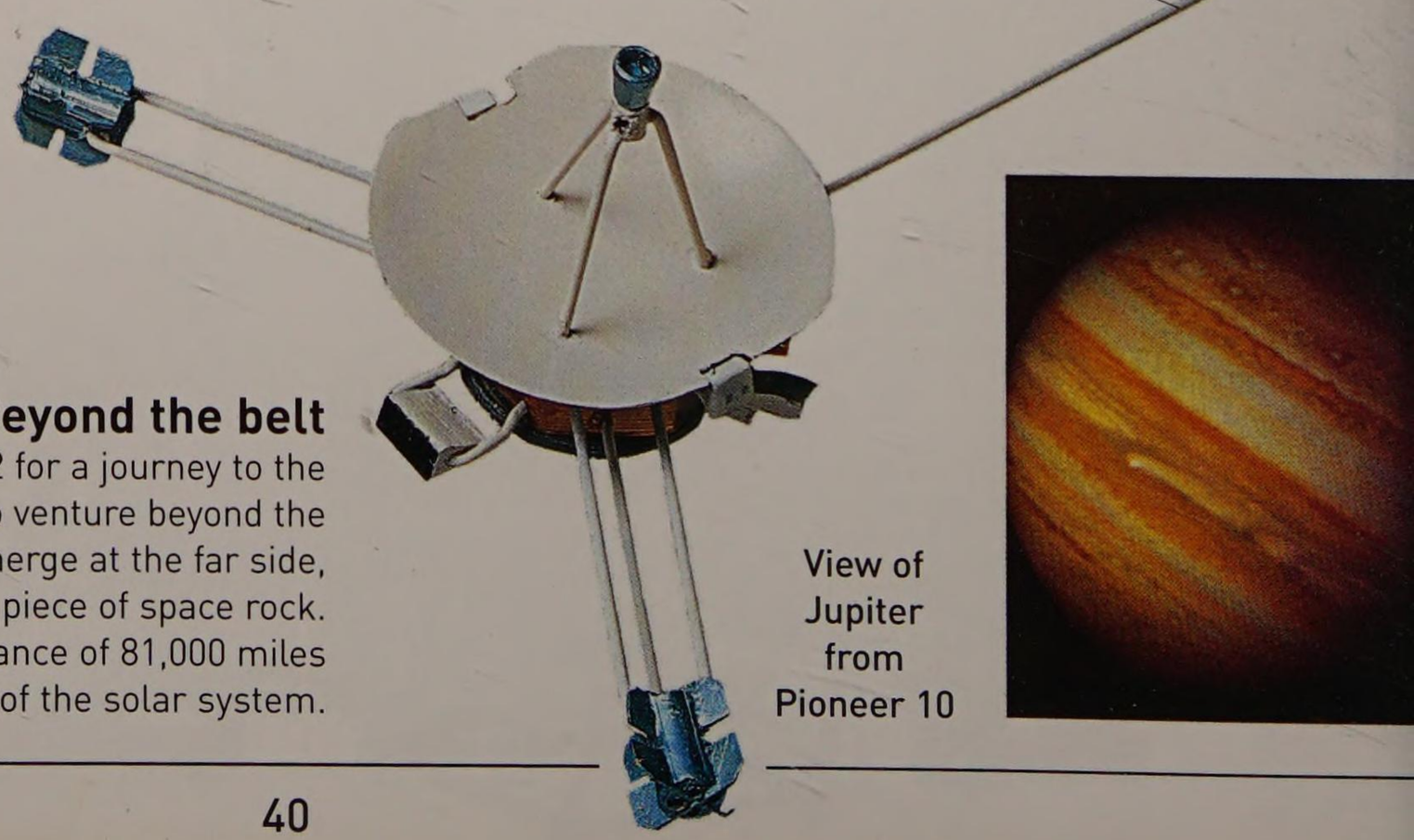


Sunny outlook
There is always vigorous activity on the Sun's surface. Every day, SOHO pictures the whole Sun at four ultraviolet wavelengths (shown here), which correspond to different temperatures in the Sun's atmosphere.





Message from Earth
Before the probes Pioneer 10 and Pioneer 11 were launched in 1972 and 1973 respectively, they were equipped with messages in case any extraterrestrials came across them. The messages were etched on a 6 in (15 cm) x 9 in (23 cm) gold-covered aluminum plaque.



Beyond the belt
Pioneer 10 left Earth in 1972 for a journey to the planet Jupiter. It was the first probe to venture beyond the asteroid belt. It took six months to emerge at the far side, successfully avoiding a collision with a piece of space rock. The probe flew by Jupiter at a distance of 81,000 miles (130,300 km) before heading for the edge of the solar system.

View of Jupiter from Pioneer 10

Target Jupiter

Galileo started its journey to Jupiter in 1989. Powered by electricity produced by the natural radioactive decay of plutonium, the main craft went into orbit around Jupiter in 1995. A smaller probe was released into Jupiter's atmosphere and, for 57 minutes, relayed data back to Earth. Galileo was plunged into Jupiter's atmosphere in 2003, to end its mission.

This part of the probe counter-tates to provide ixed position for the camera and other sensors

Low-gain antenna

High-gain antenna

Three ribs did not open, disabling the high-gain antenna

Boom with sensors to measure magnetic field

Thruster used to put Galileo into orbit around Jupiter

One of two generators viding power

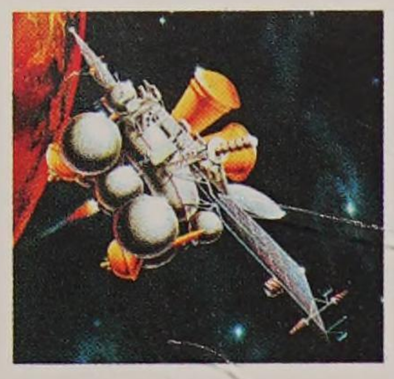
Gaspra, an asteroid, 12 miles (19 km) long

Asteroid ring

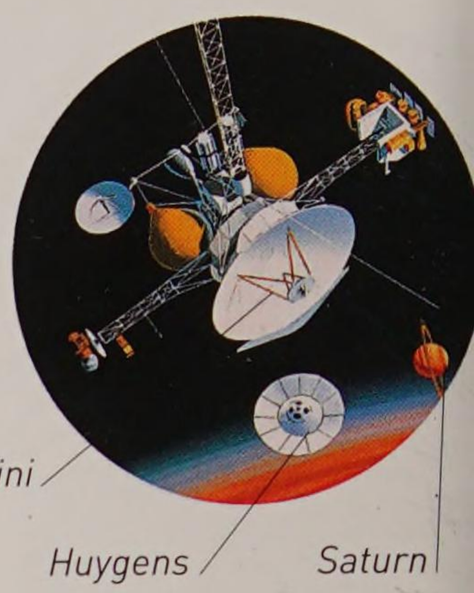
The asteroid belt lies between Mars and Jupiter. It is a ring-shaped collection of billions of rocks. Some large ones are a few hundred miles across.

Space investigators

On board a space probe are around 10 to 20 highly sensitive scientific instruments. These instruments record, monitor, and perform experiments for Earth-based scientists. The information they supply enables astronomers and space scientists to build up a picture of the objects in space. The instruments are perhaps the most important part of a space probe.



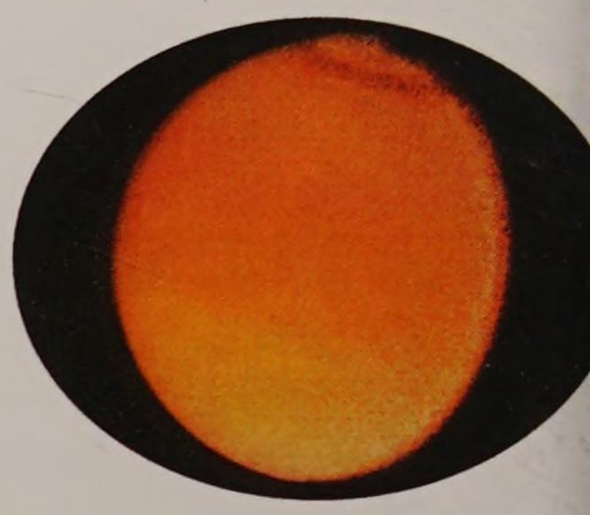
Probe life
Space probes travel hundreds of millions of miles from Earth. Not every probe completes its mission.



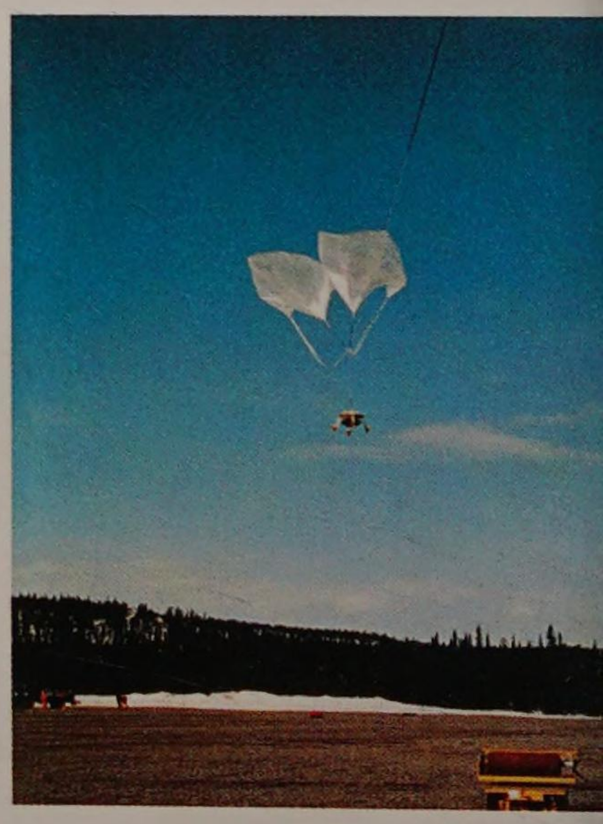
Saturn prob
In 2004, the Cassini pro reached Saturn after a journ lasting nearly seven yea Cassini orbited the plan before releasing a small prob Huygens, which reached Tita Saturn's largest moon, in 200

Naming names
The European Space Agency's (ESA's) probe to Halley's Comet was called Giotto, after painter Giotto di Bondone. His 1305 fresco *Adoration of the Magi* depicts a cometlike star.

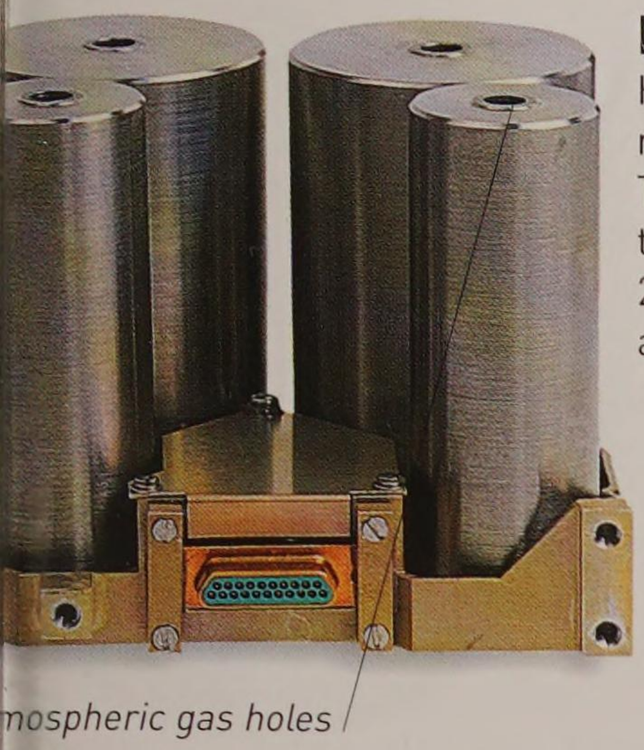
Giotto
The ESA's Giotto traveled toward Halley's Comet in 1986. Giotto approached the comet at 149,000 mph (240,000 kph) and traveled through a halo of gas and dust before getting within about 375 miles (600 km) of the comet's nucleus.



Titan
Titan is shrouded by a thick, orange, nitrogen-rich atmosphere. The Huygens probe touched down on the Moon's surface on January 14, 2005.



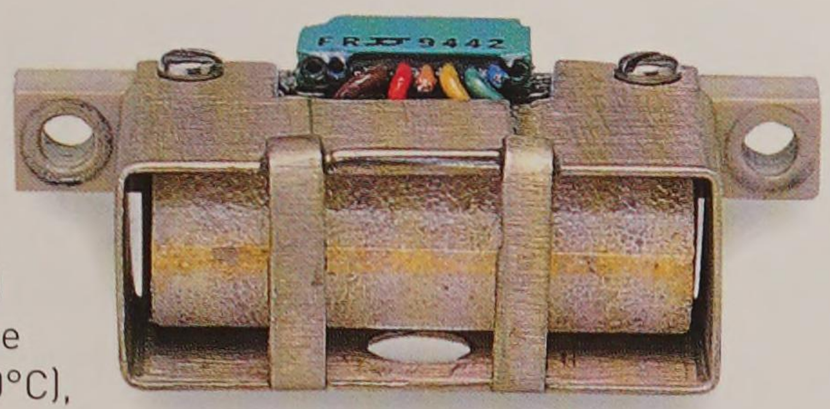
Testing Huyger
Parachutes controlled t descent of Huygens, the probe's instruments we set to work. Here, a prob descent is practiced on Ear



mospheric gas holes

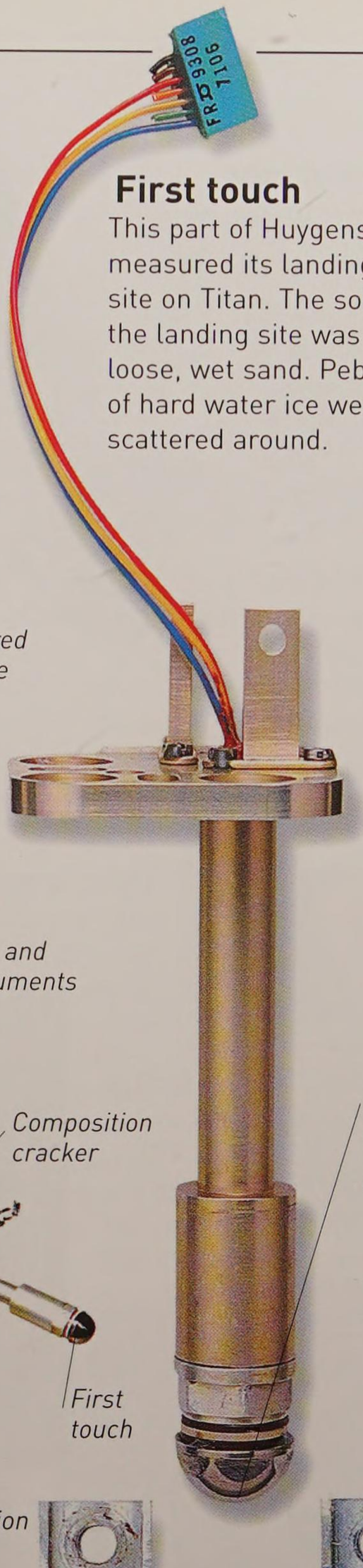
How cold?

Huygens measured Titan's temperature 25 miles (40 km) above the surface as –325°F (–200°C), and its surface as –290°F (–180°C).



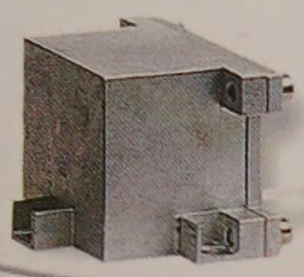
Density

This instrument was meant to measure the density of Titan's liquid ocean—but the probe hit dry land.

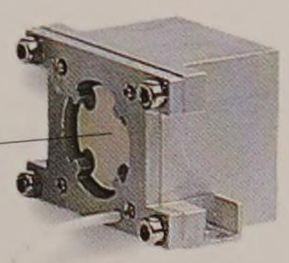


First touch

This part of Huygens measured its landing site on Titan. The soil at the landing site was like loose, wet sand. Pebbles of hard water ice were scattered around.



Transmitter sent "beeps"



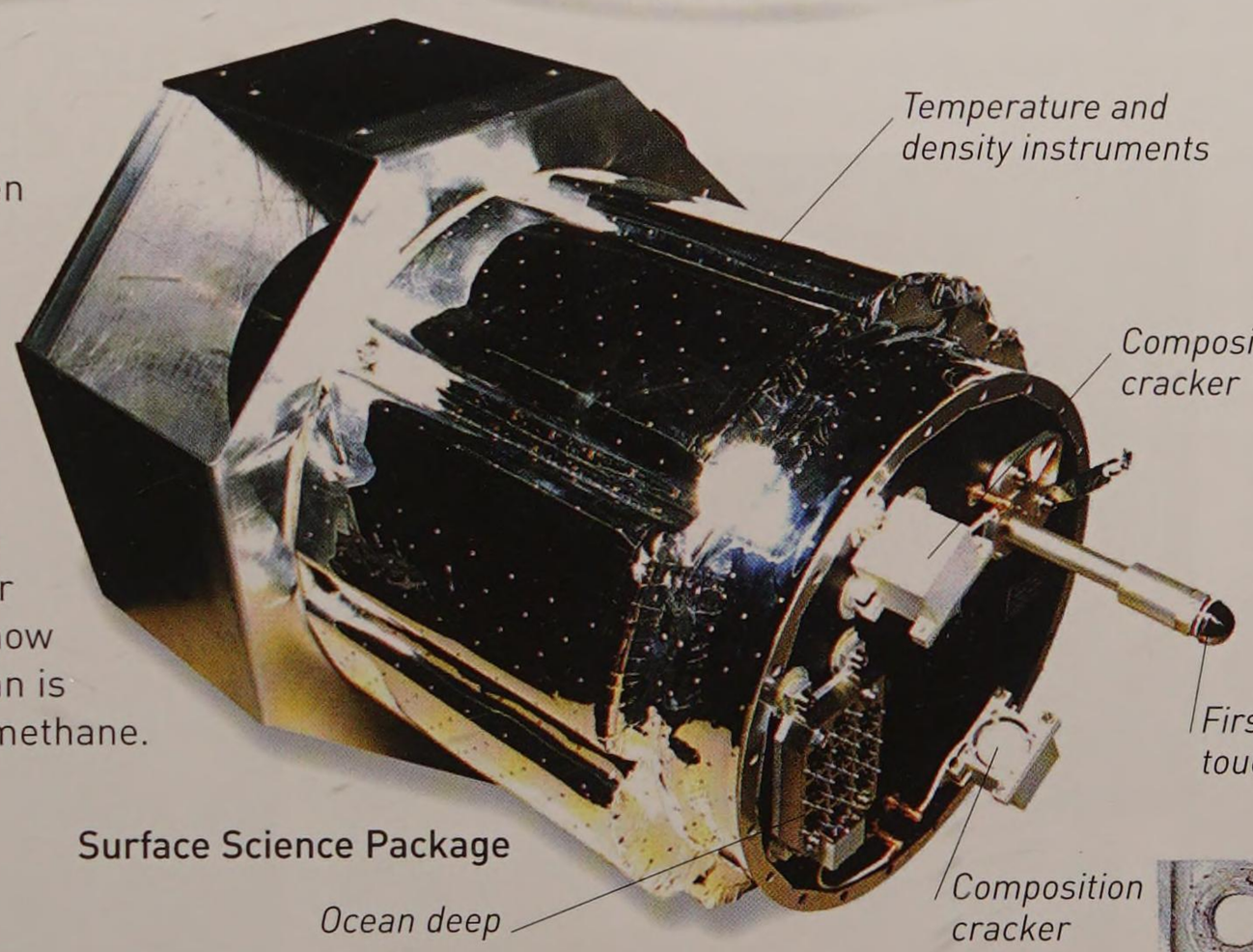
Cable transferred data for storage

omposition cracker

measuring these instruments' eeps," scientists found that Titan's mosphere was 98.4 percent nitrogen d 1.6 percent methane.

Top-hat science

The five experiments in this top-hat sized piece of equipment, alled the Surface Science Package (SSP), measured Titan's lower atmosphere and surface. We now know that the cold soil on Titan is often saturated with methane.



Temperature and density instruments

Composition cracker

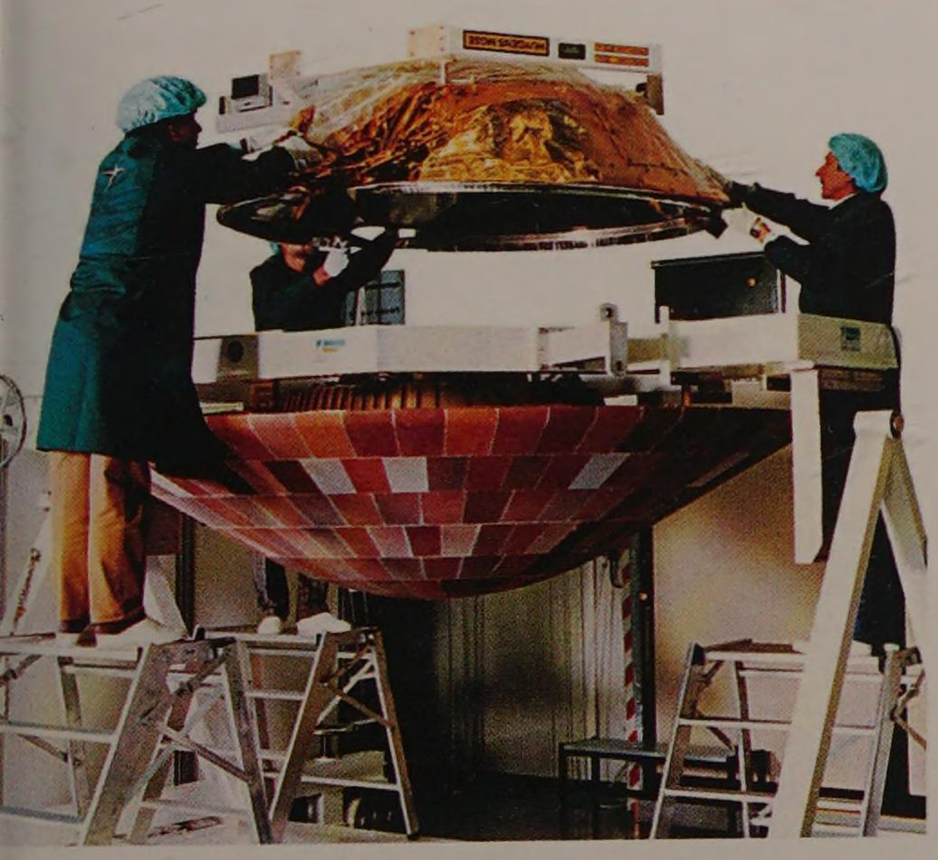
This part touched Titan's surface

First touch

Surface Science Package

Ocean deep

Composition cracker



ay cool

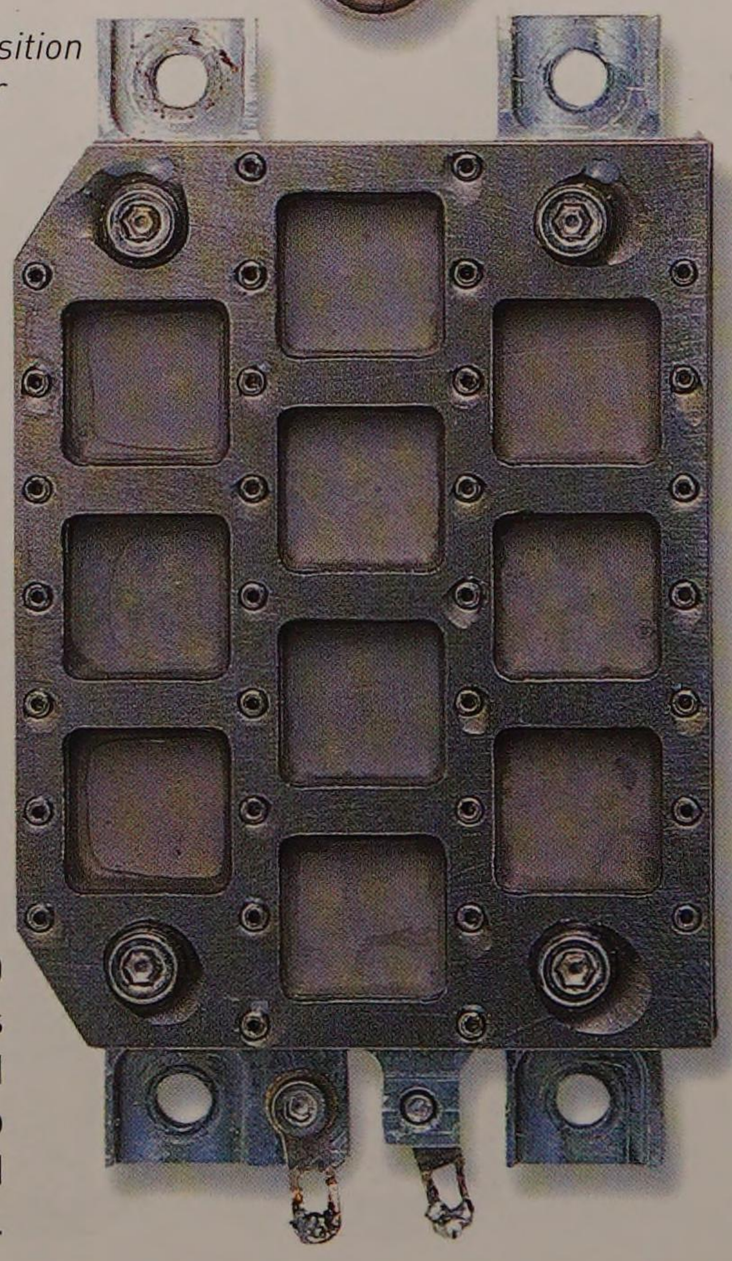
re, space technicians fit the heat shield on ygens. The shield protected the craft from mperatures of up to 3,600°F (2,000°C).

Descent to Titan

Huygens took about 2 hours, 28 minutes to reach the surface of Titan, and sent data for about 90 minutes after landing.

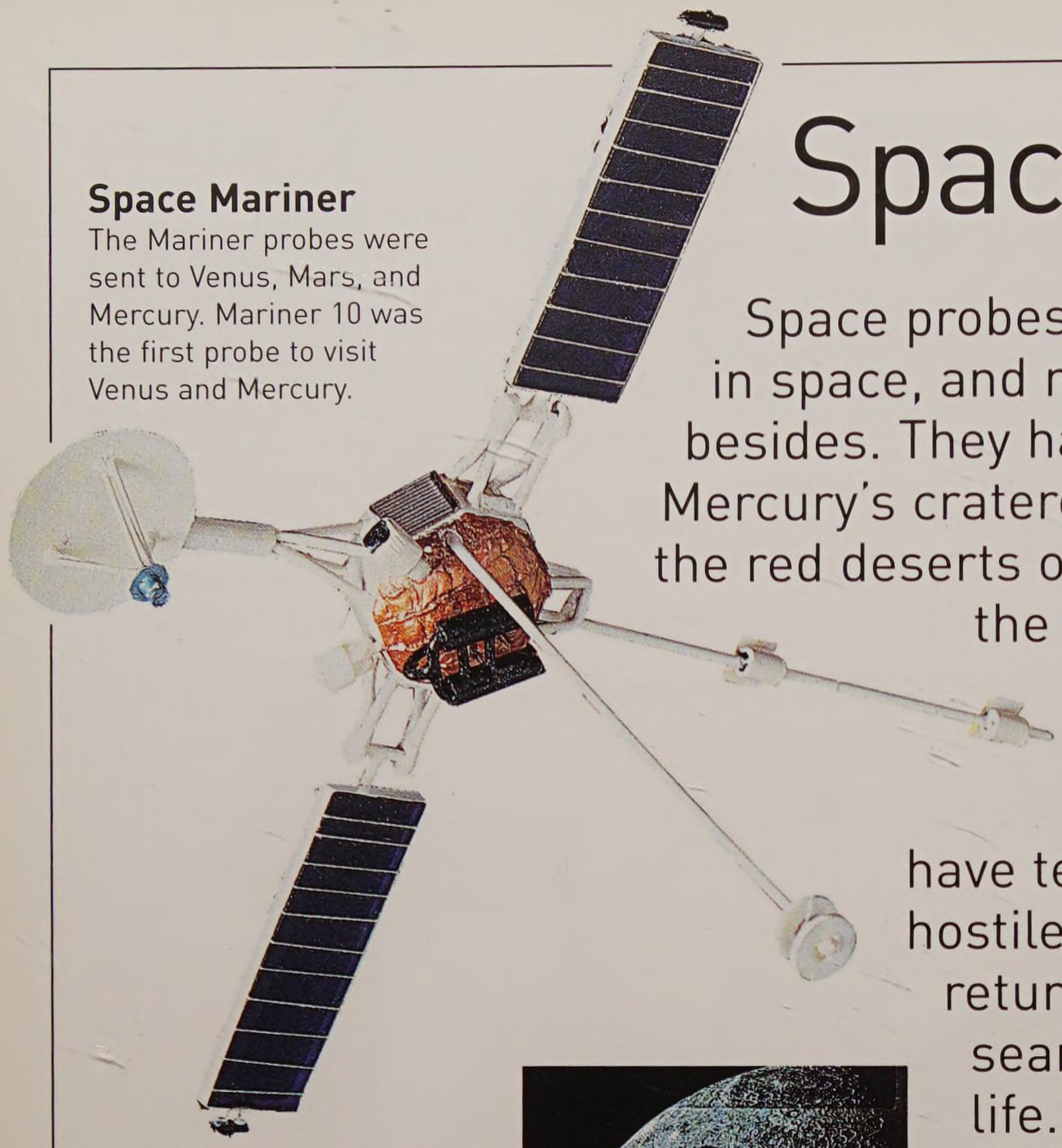
Ocean deep

If Huygens had landed in water, this instrument would have measured its depth. Titan's seas are made up of the hydrocarbons methane and ethane in liquid form.



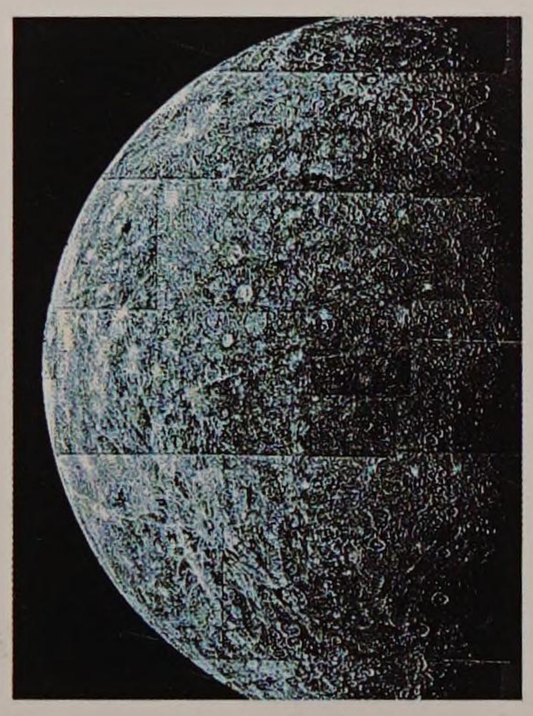
Space discoverers

Space probes are our eyes in space, and much more besides. They have shown us Mercury's cratered terrain, the red deserts of Mars, and the mountains and plains beneath the Venusian clouds. They have tested thick, hostile atmospheres, returned Moon rock to Earth, and searched Martian dust for signs of life. Much of our knowledge about the solar system comes from probes.



Space Mariner
The Mariner probes were sent to Venus, Mars, and Mercury. Mariner 10 was the first probe to visit Venus and Mercury.

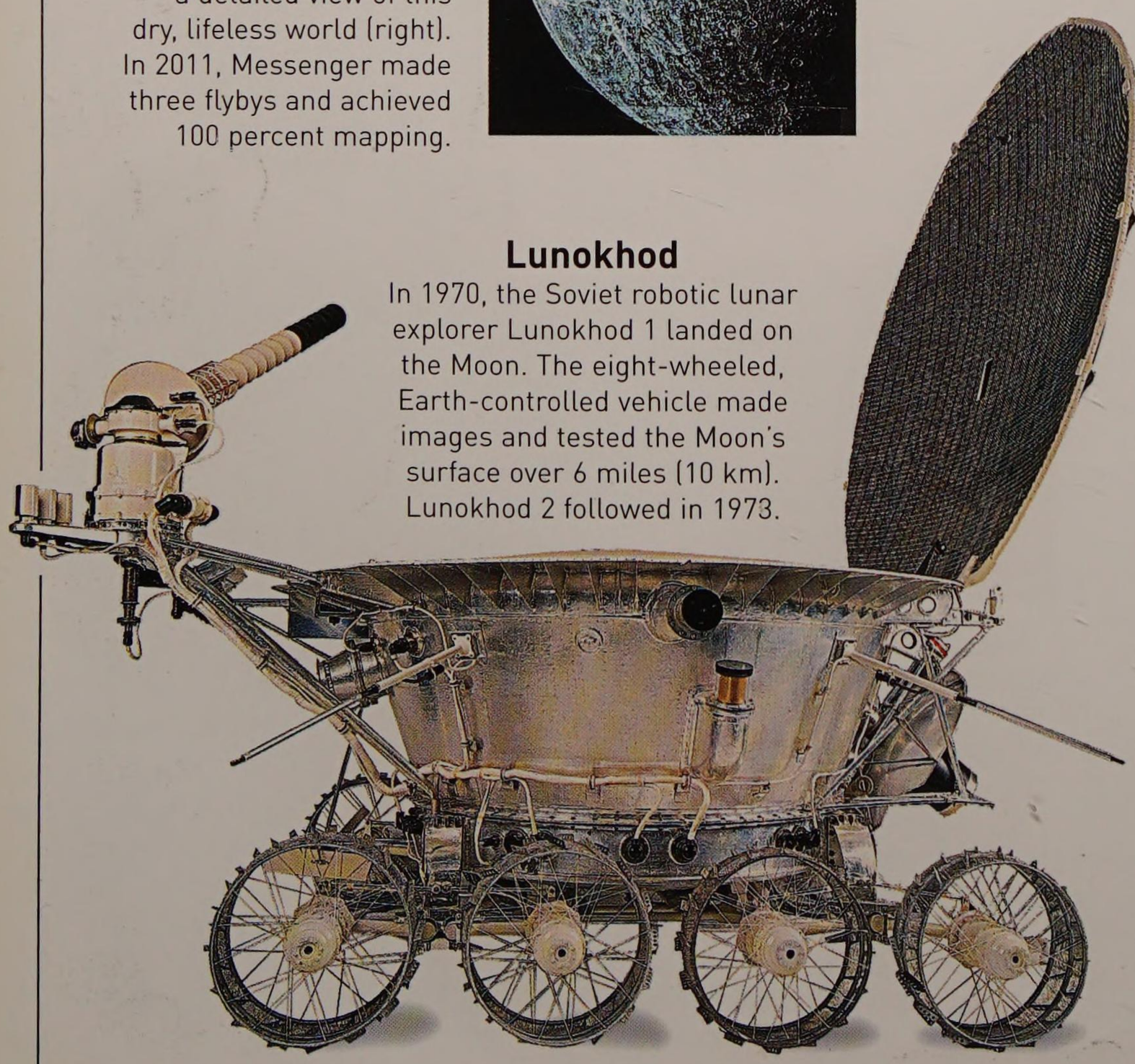
Venus revealed
The surface of Venus is hidden by its dense, hostile atmosphere. This globe was made using radar images from Magellan in 1992.

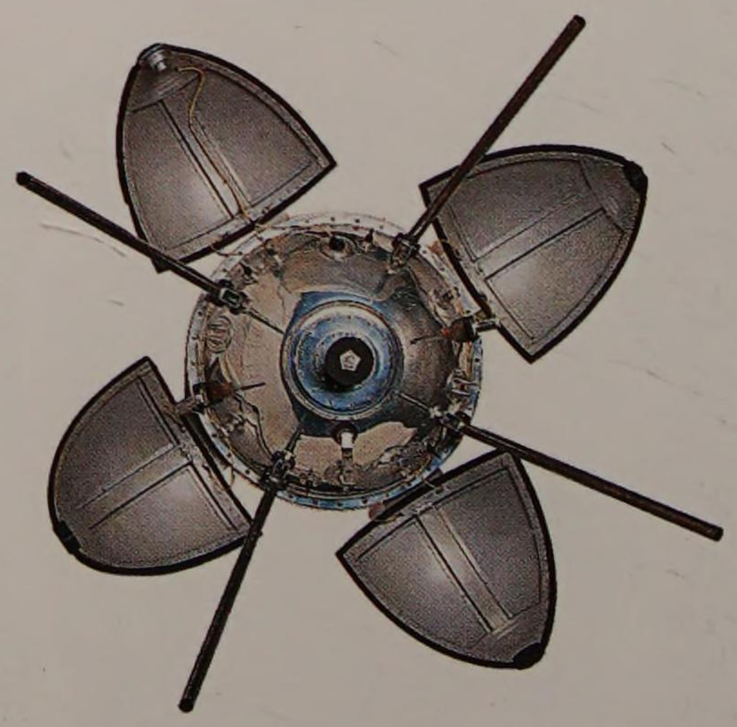


Mercury in focus
Only two probes have visited Mercury. In the early 1970s, Mariner 10 approached the planet three times and made more than 10,000 images, which produced a detailed view of this dry, lifeless world (right). In 2011, Messenger made three flybys and achieved 100 percent mapping.

Moon side
Since 1959, US, Soviet, European, Japanese, Chinese, and Indian craft have visited the Moon. These spacecraft have shown us what the far side of the Moon looks like.

Lunokhod
In 1970, the Soviet robotic lunar explorer Lunokhod 1 landed on the Moon. The eight-wheeled, Earth-controlled vehicle made images and tested the Moon's surface over 6 miles (10 km). Lunokhod 2 followed in 1973.





Moon detectives
The Soviet Luna space probes were the first to travel to the Moon, to image the far side, and to orbit it. In 1966, Luna 9 made the first soft landing and took the first panoramic pictures of the Moon's surface.

Venera to Venus

Between 1961 and 1983, the Soviet Venera space probes were sent to Venus. In 1967, Venera 4 transmitted data for 94 minutes as it descended through Venus's clouds, before being crushed by the atmosphere.

Discovering Mars

A total of 16 space probes were sent to Mars between 1962 and 1975. The first flew past the planet, while later probes orbited it. The final two craft landed on it.

Mars 3 lander opened to expose its scientific experiments

Lander released by Mars 3 as it orbited Mars

ommunications enna sent data back to Earth

ar panels converted unlight to electricity

Equipment measured atmosphere and magnetic field

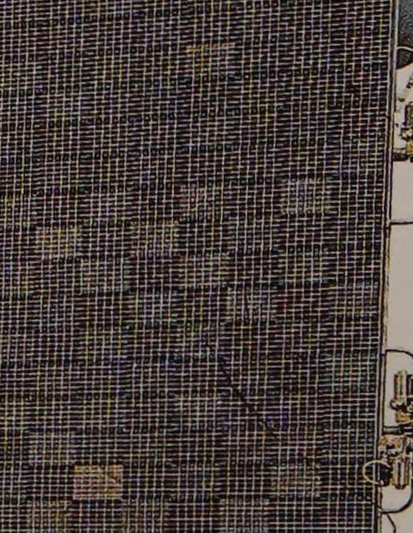
Display stand supported the spacecraft

Viking landers

Two identical craft were launched to Mars in 1975. They each had an orbiter, with television cameras to photograph Mars, and a lander. They found no life on the planet.

Mars craft

The craft studying Mars in 2014 included the rovers Opportunity and Curiosity; the Express, Mars Reconnaissance Orbiter, and Mars Odyssey; and the Mars Orbiter Mission and MAVEN.

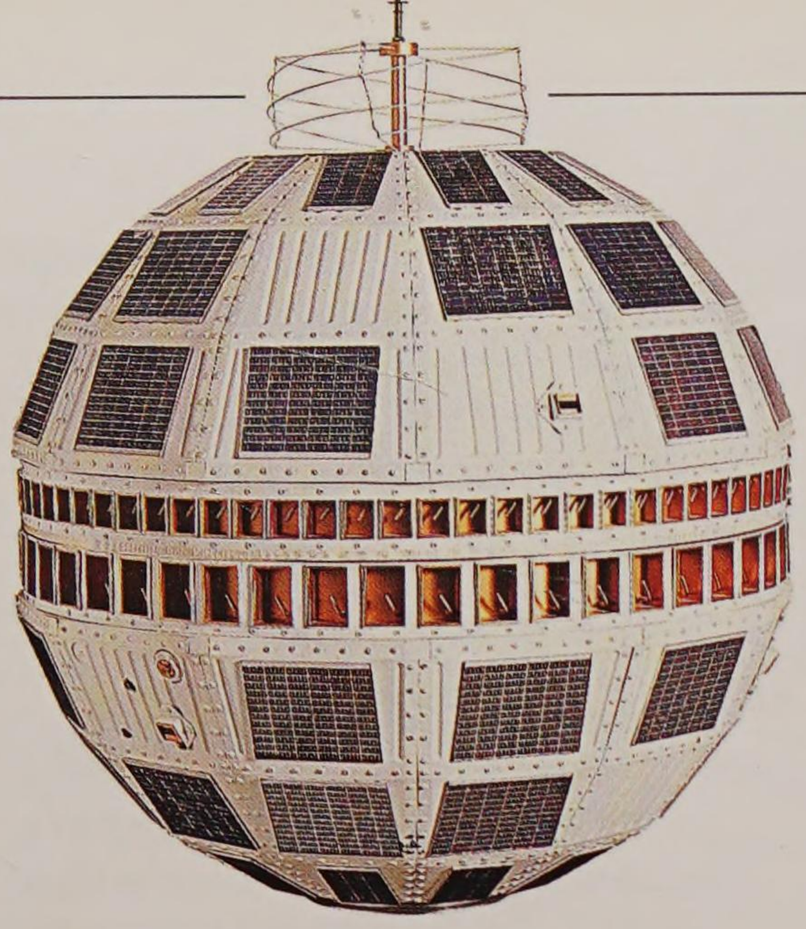


Mars 3

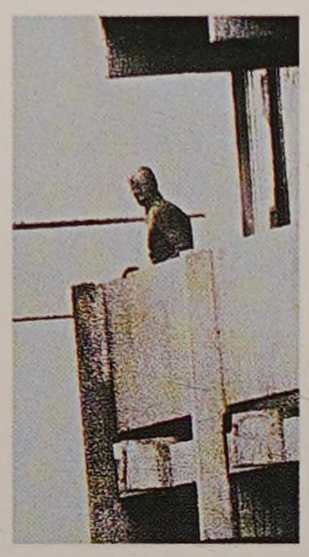
Mars 3 reached Mars in 1971. A probe landed safely on the planet's surface, yet only 20 seconds after touchdown, transmission of data stopped. The probe may have been buried by a dust storm.

Satellite space

The Moon is Earth's only natural satellite and its closest neighbor in space. In between is the virtual vacuum of space and more than 1,000 operational satellites. Each one is a specialized instrument orbiting Earth. Arguably, the most important are the telecommunications satellites. They give us global communications, television pictures, and are used in all types of business.



Telstar
The first transatlantic live television pictures were transmitted in 1962 by Telstar, a round, 35-in- (90-cm-) wide satellite covered in solar cells.



Terrorist at Munich Olympics

Opening ceremony of Beijing Olympics, China, 2008

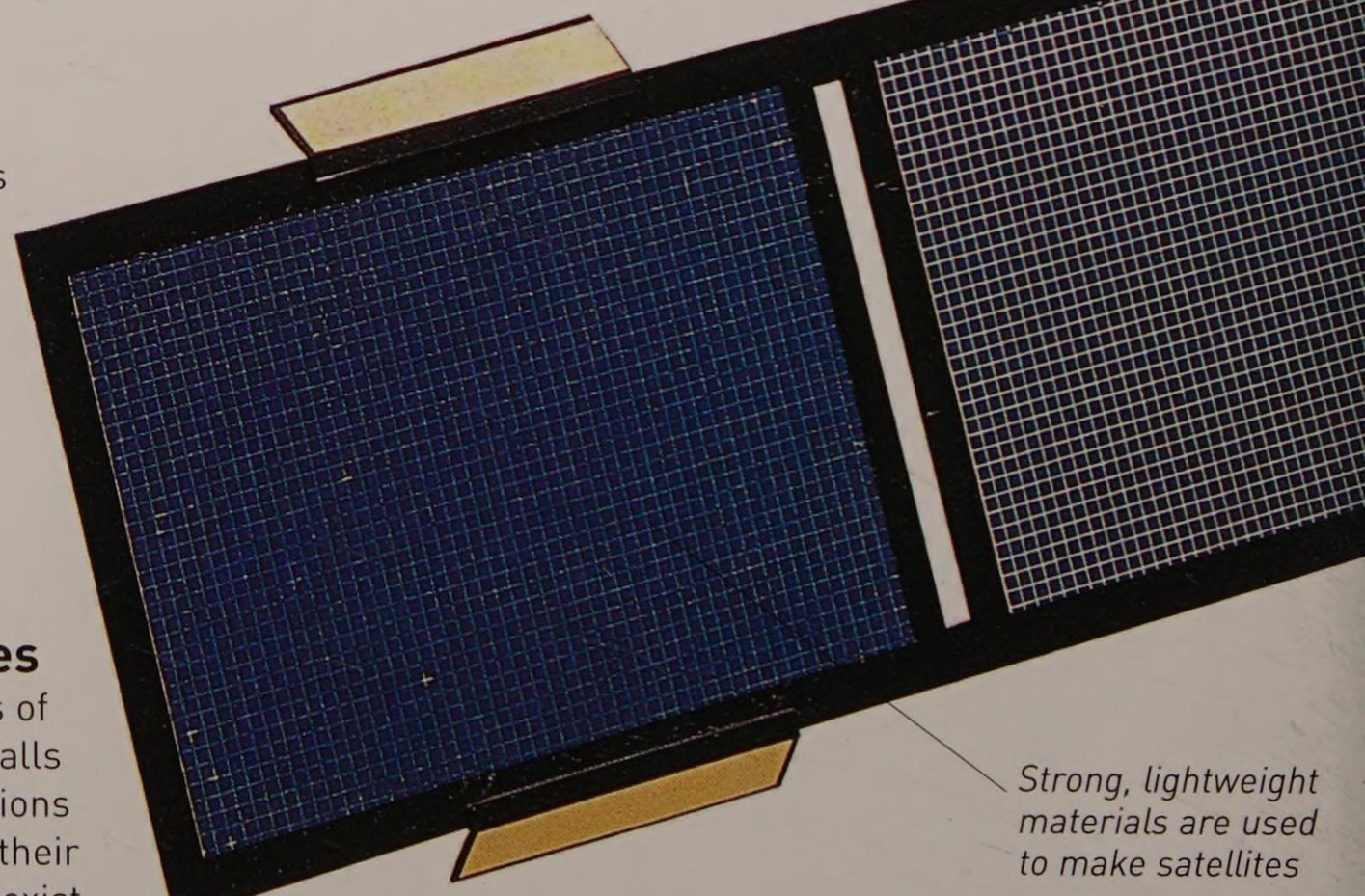
Global news

Satellites can turn a local occasion into a global experience, which billions of people can watch as events unfold. In 2008, a TV audienc of more than three billion worldwide saw the opening ceremony of the Beijing Olympic Games.

Pocket-sized navigation system

Navigation

The Global Positioning System (GPS) uses a set of 31 satellites in orbit around Earth. The user sends a signal from a handset, which is received by up to 12 of the satellites. By return, the user learns his or her location.



Strong, lightweight materials are used to make satellites

Busy lines

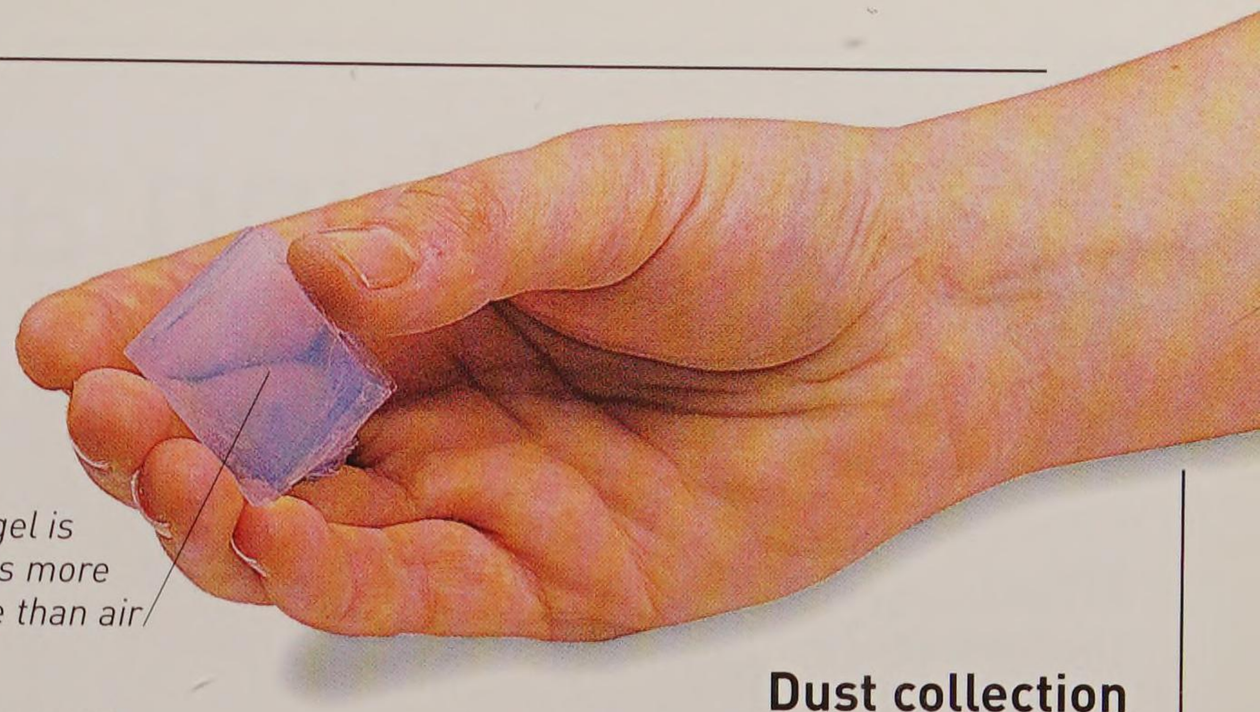
A telecommunications satellite has to handle tens of thousands of phone calls at once. In the 1980s, calls across Europe used the European Communications Satellite (ECS). Other areas of the world developed their own systems. Today, global systems exist.

Ground control

Satellites are launched by rocket. Once the satellite has separated from the launcher, an onboard motor propels it into its correct orbit. Smaller maneuvers are made by the satellite's propulsion system to maintain its correct position in space. A satellite control center tracks the satellite, receives its signals, and sends it commands.

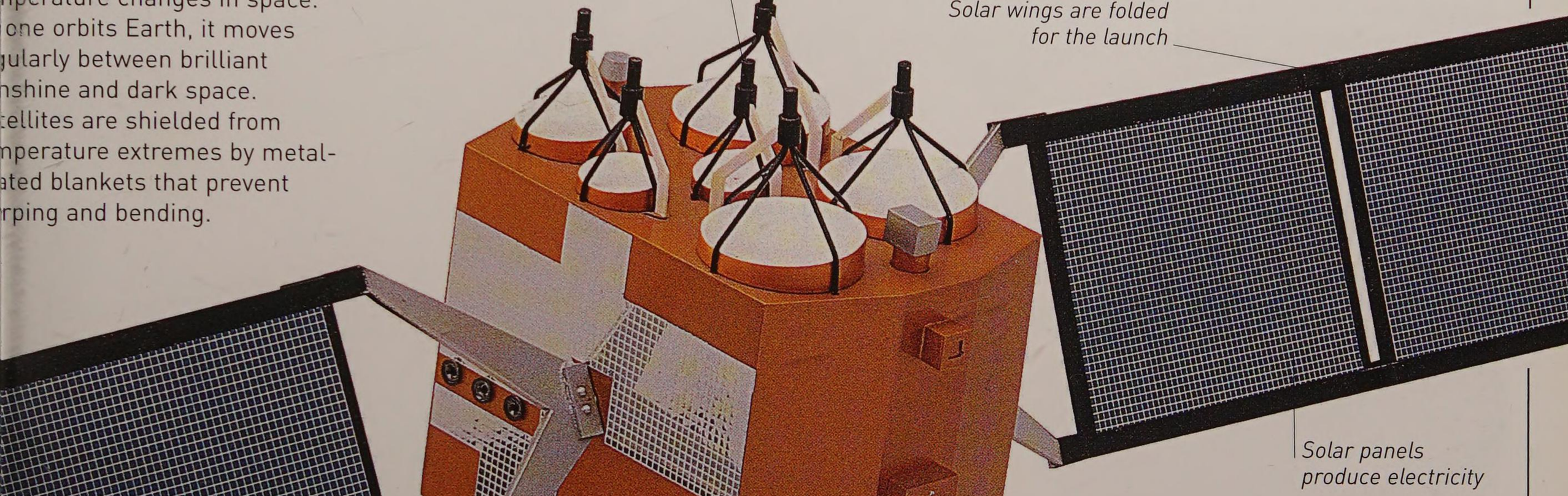
ot and cold

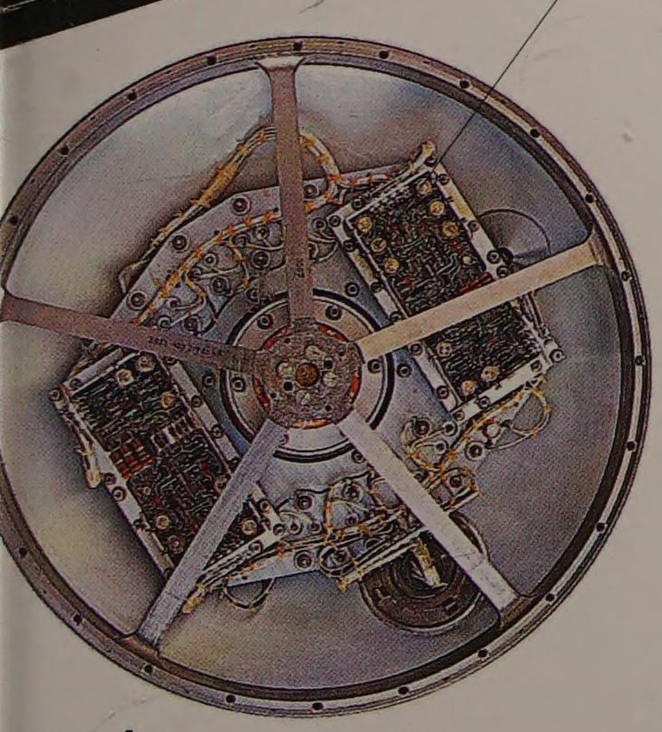
tellites are subject to large mperature changes in space. one orbits Earth, it moves gularly between brilliant nshine and dark space. tellites are shielded from mperature extremes by metal- ated blankets that prevent rping and bending.



Dust collection

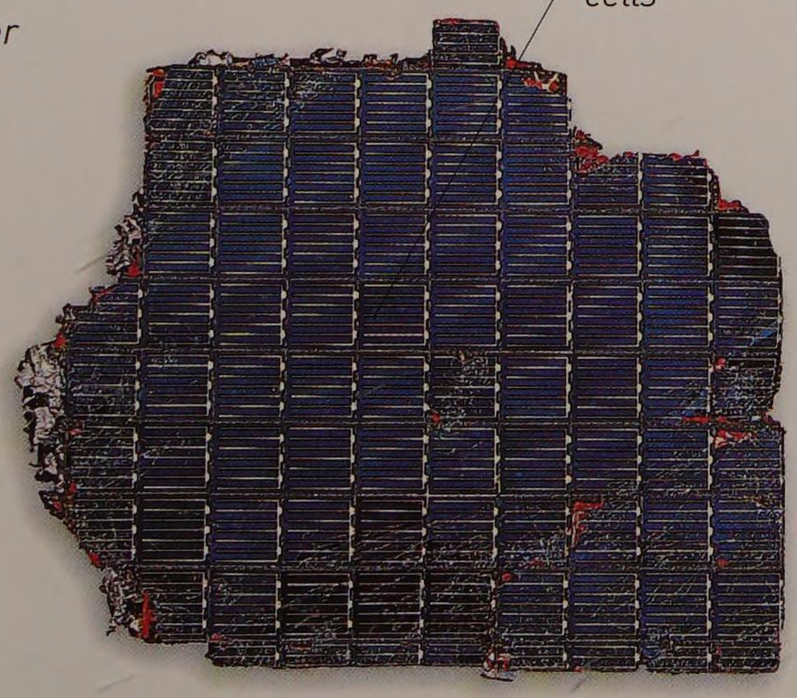
Scientists can learn about space from dust particles. These particles can be collected by aerogel, a material covering the outside of a satellite.





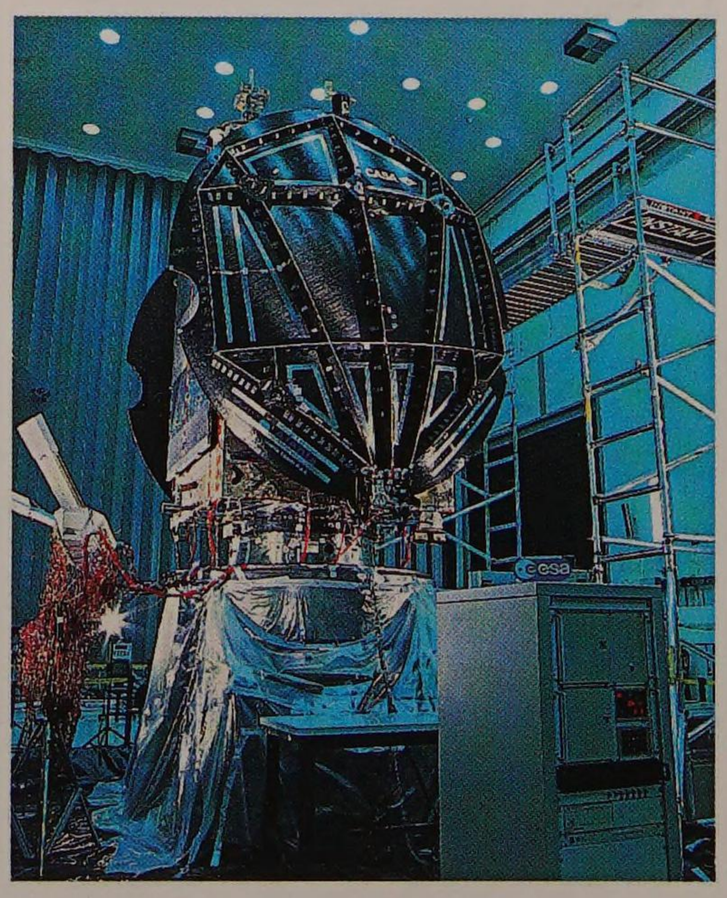
a spin

a satellite orbits Earth, different rts of it need to point in particular rections at one time. A gimbal device, e this one, keeps the satellite tennae pointing toward Earth.



Breakup

Satellites are built to work in space for several years. But it takes only one part of a satellite to malfunction and the satellite is dead. This piece of solar panel, for example, took a battering in space.



Shake, rattle, and roll

Before a satellite reaches orbit and becomes operational, it has to survive the vibrations at the launch. Artemis, an experimental telecommunications satellite, is shown here being tested on a shaker that simulates launch conditions. Artemis was placed in orbit above Earth in 2001.

Looking at Earth

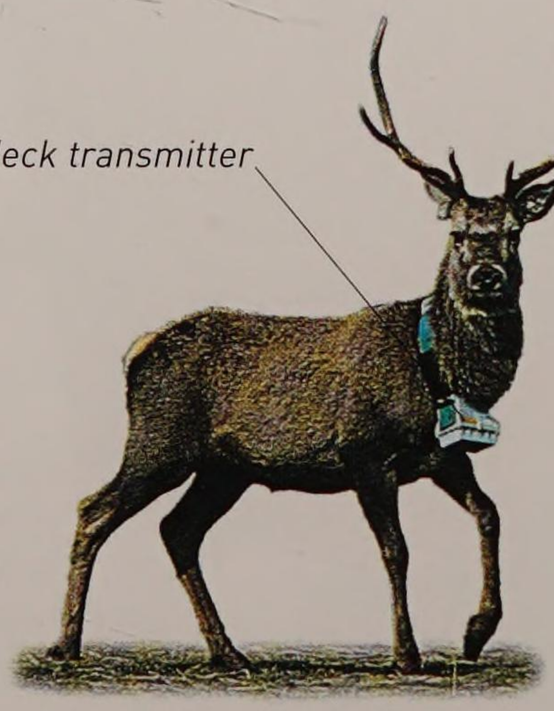
Satellites are continually taking a close look at our planet. Each one concentrates on collecting a specific type of information. Weather satellites study clouds, and the Earth's atmosphere, or record its surface temperatures. Man-made structures and natural resources are mapped by other satellites. By taking time-lapse images of Earth, satellites also make records of planetary changes.

Paris

ERS-1
The European Remote Sensing (ERS) satellite, ERS-1, made these four views of Europe (above and in the other page corners) in 1992. Landsat 8, launched in 2013, is a recent American satellite to monitor Earth.

Man-made disaster
The Landsat 5 satellite shows a vas oil slick on the Saudi Arabian coast 1991. False colors have been added to the image.

Bird spotting
The fish-eating Steller's sea eagle breeds in far eastern Russia. Satellite tracking follows the birds as they fly south to spend winter on the Japanese island of Hokkaido.



Deerstalker
Transmitters picked up by satellite are sometimes attached to animals, like this red deer. Conservationists can then protect the sites where such animals breed, feed, and spend winter.

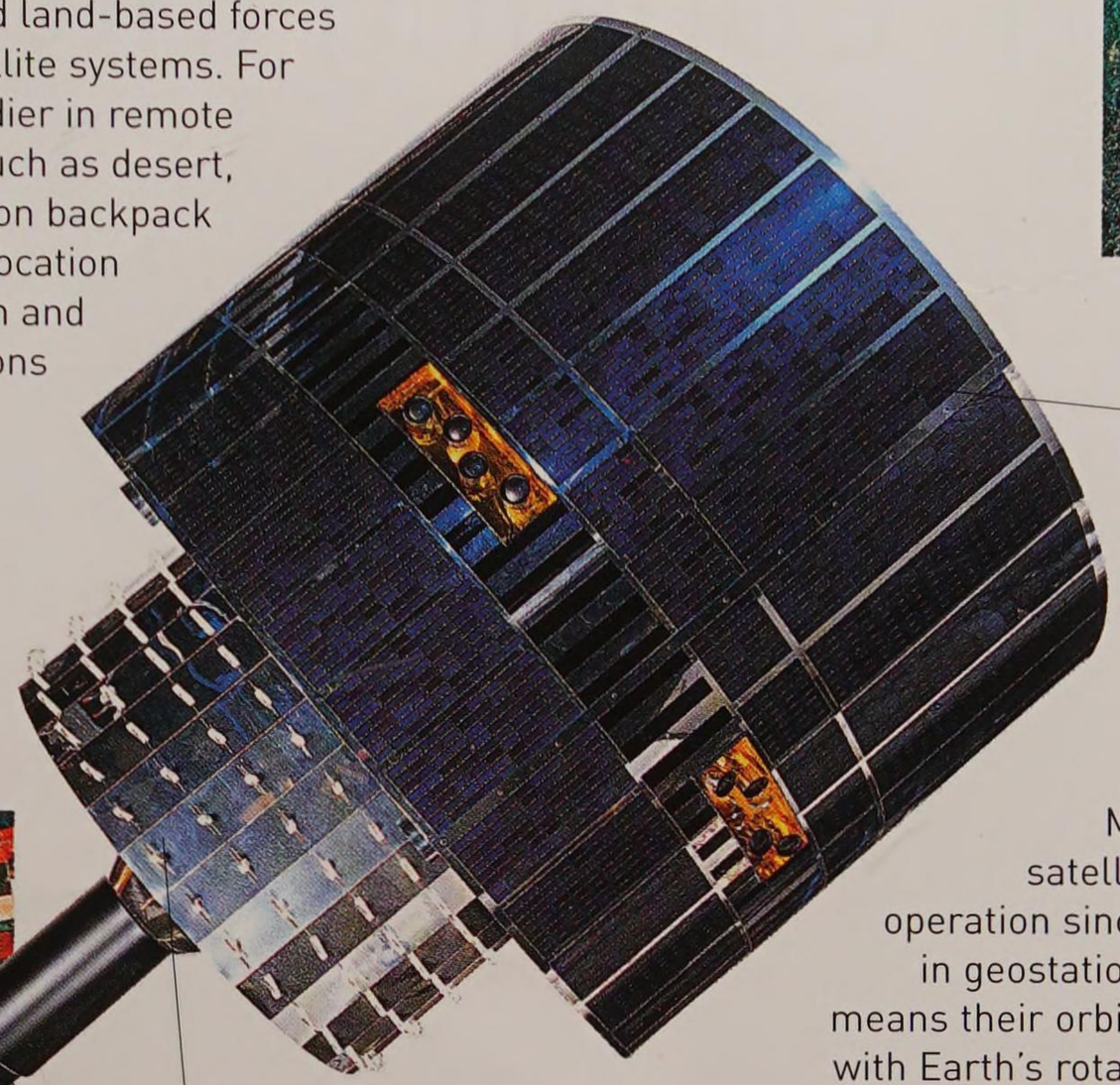
London

Eye in the sky
The French observation satellite, Spot-1, photographed the whole of Earth's surface every 26 days since its launch in 1986. On board were two telescopes, each observing a 37 mile (60 km) wide strip of land below the satellite. This Spot-1 picture of farmland in Canada was made in 1988.

Portable satellite dish

Man on the move

Air-, sea-, and land-based forces all use satellite systems. For a lone soldier in remote terrain, such as desert, a navigation backpack provides location information and gives directions on movement.



Communications equipment

Solar cells supply energy for Meteosat to function

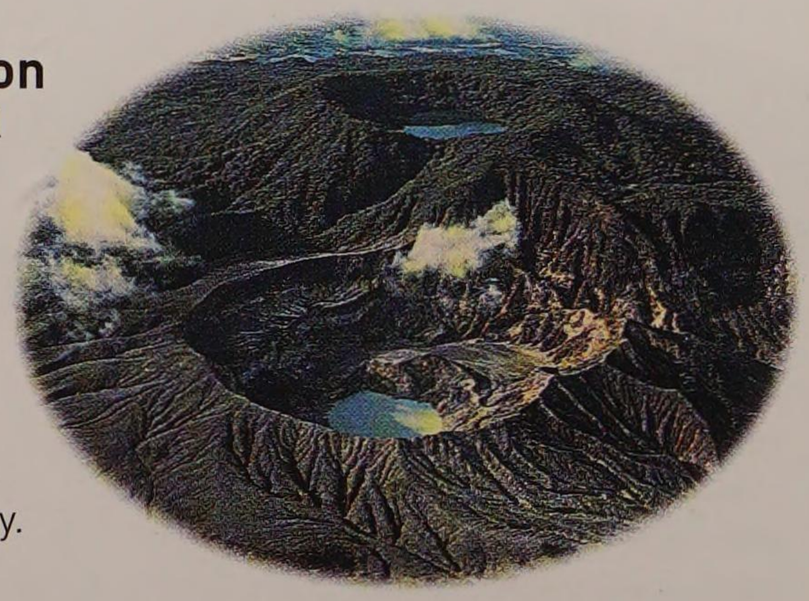
Vienna

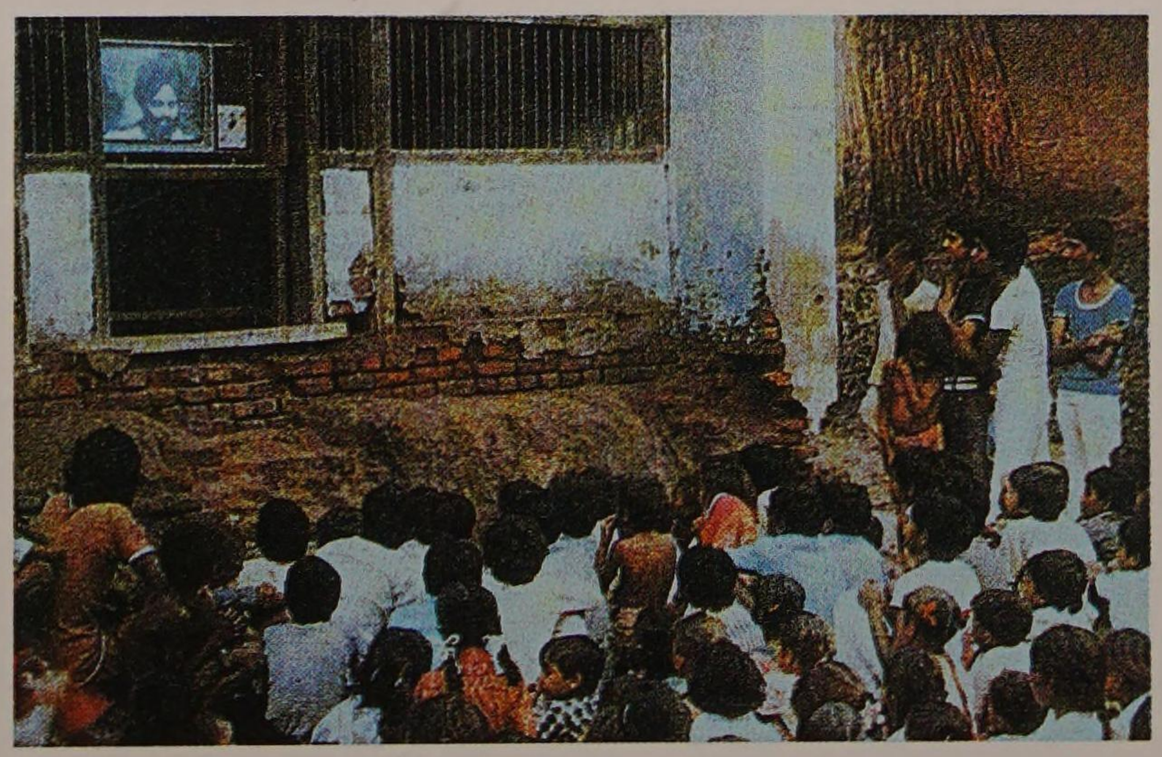
Meteosat

Meteosat weather satellites have been in operation since 1977. They are in geostationary orbit, which means their orbit is synchronized with Earth's rotation, so they stay above a particular spot on Earth.

Eruption

Images of natural phenomena, such as volcanoes, are made by satellites and by astronauts on board their craft. Smoke and ash from an active volcano can be monitored, and aircraft warned away.





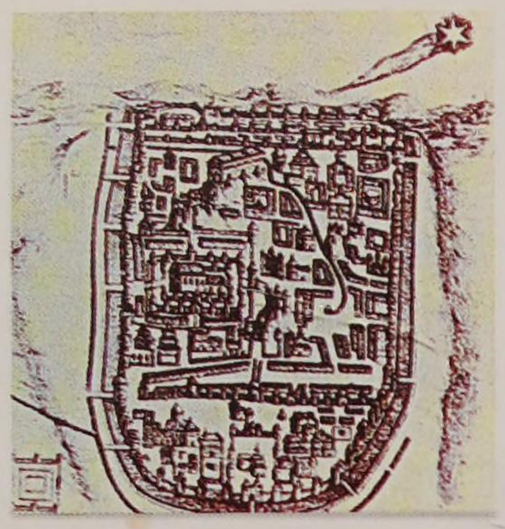
Look and learn

In 1975, more than 2,400 villages in India were given satellite dishes and televisions. Direct broadcasting by satellite instructed them on hygiene and health, family planning, and farming methods.

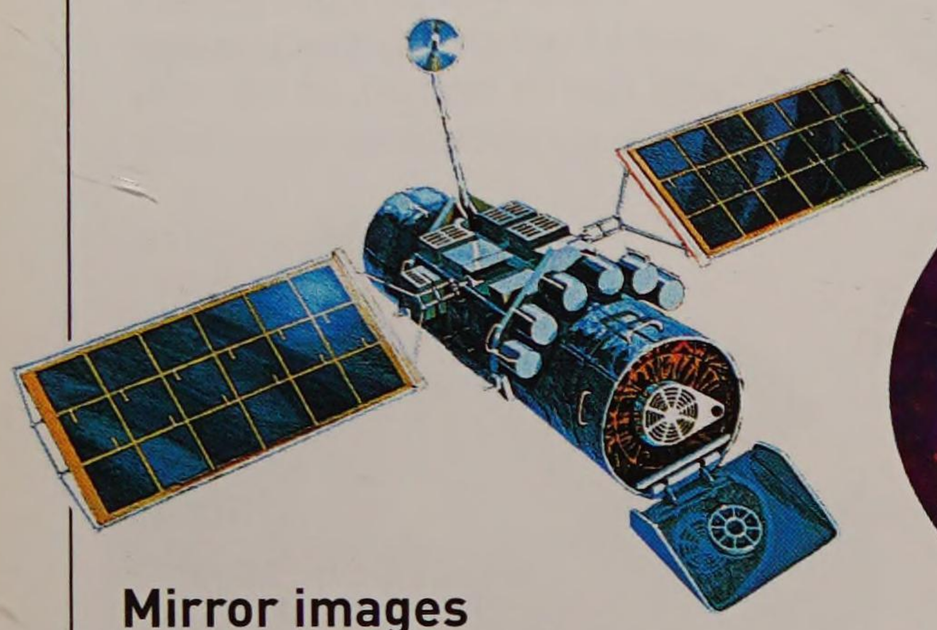
Zeeland, the Netherlands

Looking into space

Scientific satellites are used by astronomers to look away from the Earth and into space. From their vantage point, they can study the universe 24 hours a day, 365 days a year. Space telescopes operate in a range of wavelengths. Data collected by telescopes working in optical, X-ray, infrared, ultraviolet, microwave, and other wavelengths are combined to make a more complete view of space. The data then is sent to a ground station, where it is decoded by computers.



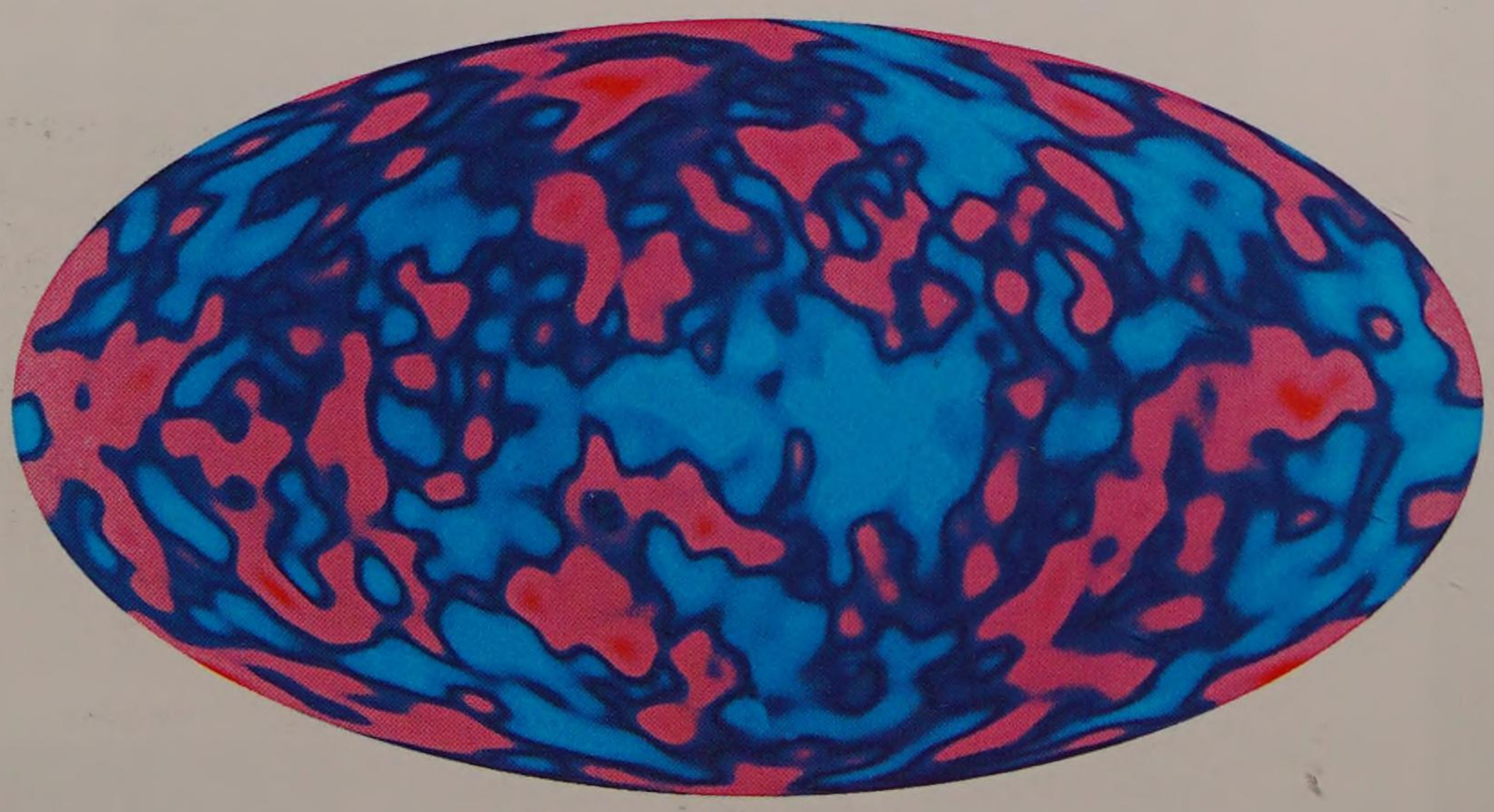
Early astronomy
Astronomers once recorded their findings in drawings, like this one. Today, electronic devices record data transmitted from telescopes in Earth's orbit.



Mirror images
Tremendous amounts of energy are needed to create X-rays, so wherever they are detected, there is violent activity. The Chandra X-ray Observatory has been imaging and studying X-ray sources since 1999.

Gas and dust clouds

Our galactic center
Data from three space telescopes are combined in this image of the central region of the Milky Way. The three, known as NASA's Great Observatories, are the Hubble Space Telescope, the Spitzer Space Telescope, and the Chandra X-ray Observatory.



Ripples in the sky
In this false-color microwave map of the sky, the temperature of the background radiation is shown as deep blue. The pink and red areas are warmer, and the pale blue cooler. These were the ripples thought to exist in background radiation created by the Big Bang.

COBE
COBE, the first satellite telescope to look at space in the microwave region, provided th first observational proof for the theor that the universe was created in a huge explosion we call the Big Bang.

unset on Saturn

e Hubble Space Telescope's
de-field planetary camera
oduced this image of Saturn,
the Sun set below Saturn's
g plane.

Hubble

The Hubble Space Telescope (HST) was launched in1990 to look at the optical and ultraviolet universe. Most satellites last only a few years, with no chance of repair. HST was designed for repair by shuttle astronauts. They could replace worn-out equipment, install new, more advanced instruments, and put the satellite back in a higher orbit. The last servicing mission in 2009 has guaranteed the HST's operation until, possibly, 2020.

ISO testing by ESA

Launch of ISO in 1995

Artist's impression of ISO

ISO picture of a supernova

Infrared observations

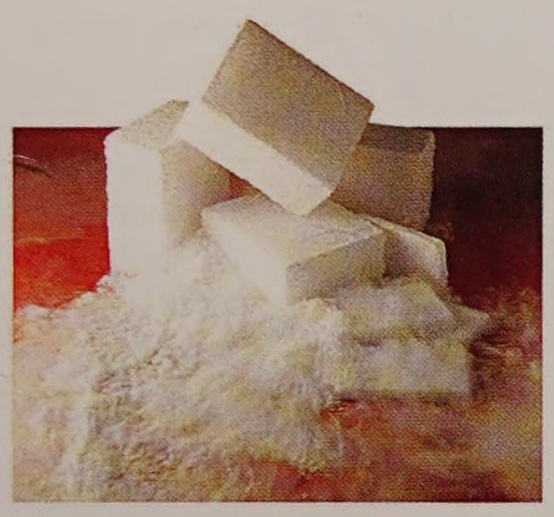
The European Space Agency's (ESA's) Infrared Space Observatory (ISO) made 26,000 scientific observations between 1995 and 1998. It took around 45 observations a day from its elliptical orbit, from 600 miles (1,000 km) to 43,500 miles (70,000 km) above the Earth.

Spin-offs

Many of the technologies and techniques designed for space have been used to benefit our lives on Earth. An everyday item such as food wrapping was developed from reflective film used on satellites. Car control systems used by one-handed drivers came from the Lunar Rover's one-handed technique. Many spin-offs from space research have also been adapted for medical use.

Laser beam
Space technology is used in equipment for people with disabilities. This boy is able to speak by using a laser beam on this headset to operate a voice synthesizer.

Insulin pump
American Robert Fischell invented an insulin pump for diabetics. Once implanted in the body, the device delivers preprogrammed amounts of insulin. The mechanism is based on pumps used on the 1976 Viking spacecraft.

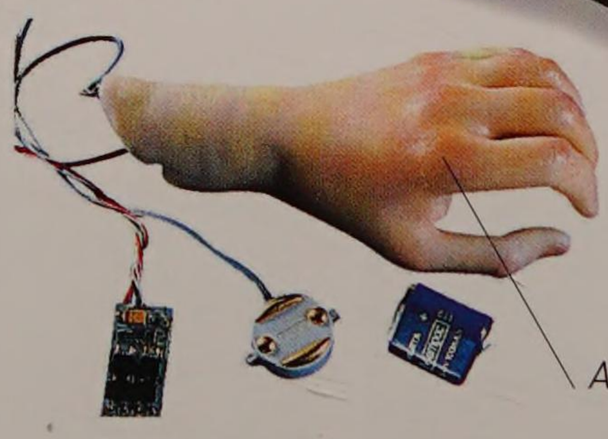


Keeping clean
A cleaning method based on space research blasts ricelike pellets of dry ice (solid carbon dioxide) at a dirty surface at supersonic speeds. On impact, the ice turns to gas and the dirt falls away.

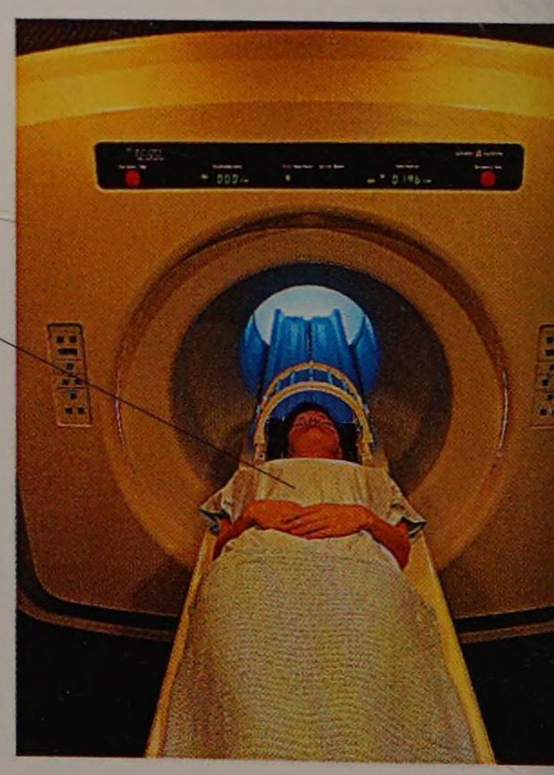
Space on the slope
The fog-free Apollo helmet design h
been adapted for use in ski goggl
Electrically heated goggles preve
moisture from condensing inside
that the goggles do not fog u

Mercury astronauts

The space look
The first US astronauts, on the Mercury rockets, wore silver suits designed to reflect heat. This space look was copied by French fashion designer André Courrèges for his collection in 1964. Within months, space-influenced fashions were available to everyone.



Hand control
The micro-miniaturization of parts for space has been adapted for Earth. Artificial limbs with controls as small as coins have been developed. This makes the limbs lighter and easier to use.



Sharp view
An image-enhancement technique that improves Moon photographs is used in medical photography. Body scanners provide a view of the inside of the human body.

ar-code systems

niaturized bar codes are etched
to tiny spacecraft parts so
entists can keep track of them.
milar miniaturized barcodes are
w used widely in manufacturing
d industry on Earth.

Brace yourself

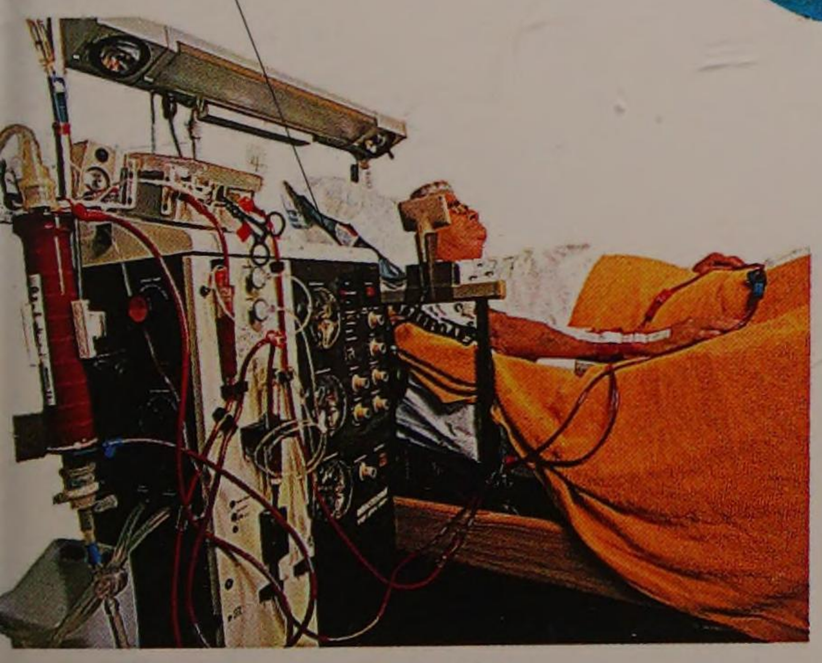
A metal alloy of nickel and titanium called nitinol is used in teeth braces. Nitinol was originally developed for space equipment such as antennae. It is an ideal material for the job because it returns to its original shape after bending. Nitinol allows braces to exert a continuous pull on teeth.

Nitinol wires held in place by colored fittings

Image shows inside and outside of hand

False color is added

idney dialysis machine



Human hand map

Techniques that enhance satellite images of the Earth are used to make maps of the human body. This computer image shows the shape and structure of a hand.

Digital display

pace help for hospitals

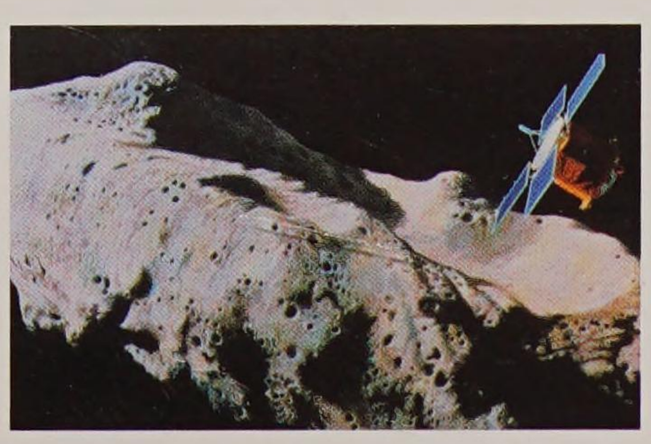
chnology used in space is found in hospitals
ound the world. Examples include reflective
nkets to retain an accident victim's body
at, kidney dialysis machines for purifying
od, special beds for burns patients, and
niaturized cameras worn on a surgeon's head.

Time under pressure

Space spin-offs are everywhere in daily life. Watches have digital displays and glass capable of surviving increased gravitational force. Some clothes are made with lightweight, thermal fabrics, qualities essential for space materials.

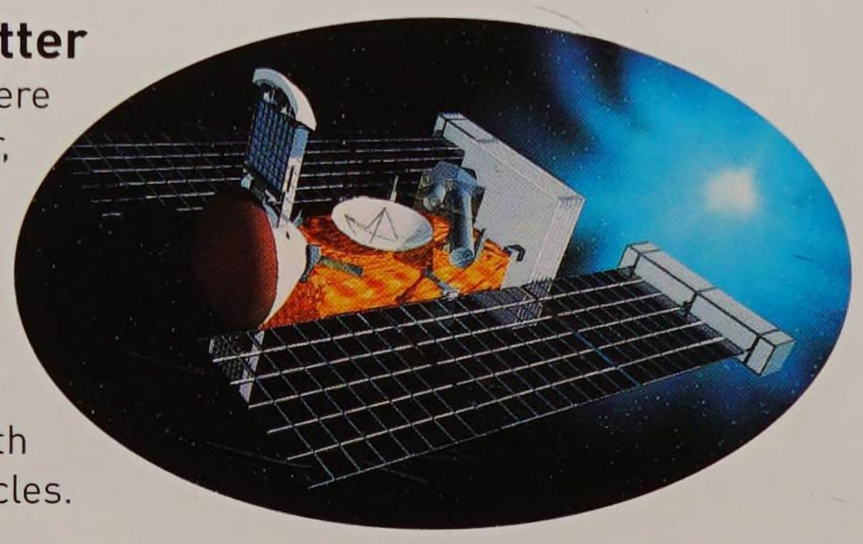
New exploration

Since the space age began, we have learned an enormous amount about the universe. The learning continues as the 21st century unfolds. Robotic probes return to worlds already seen, and investigate others for the first time. New satellites give us a global perspective of Earth, while others reveal more of the universe in deep space.



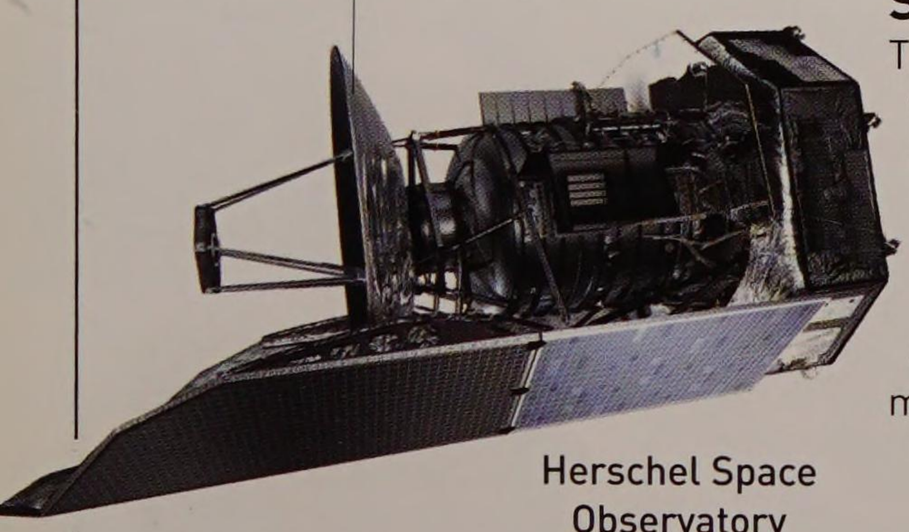
Early success
The Near Earth Asteroid Rendezvous (NEAR) probe was an early success story of the 21st century. Launched in 1996, NEAR reached its target, the asteroid Eros, in 2000. In 2001, scientists landed the probe on Eros.

Cost cutter
Some late-1990s space probes were designed to be faster, cheaper, and more effective than earlier probes. StarDust (right), launched in 1999, kept its costs down by taking seven years to complete a round-trip to Comet Wild-2. It returned in 2006 with the first comet particles.



StarDust

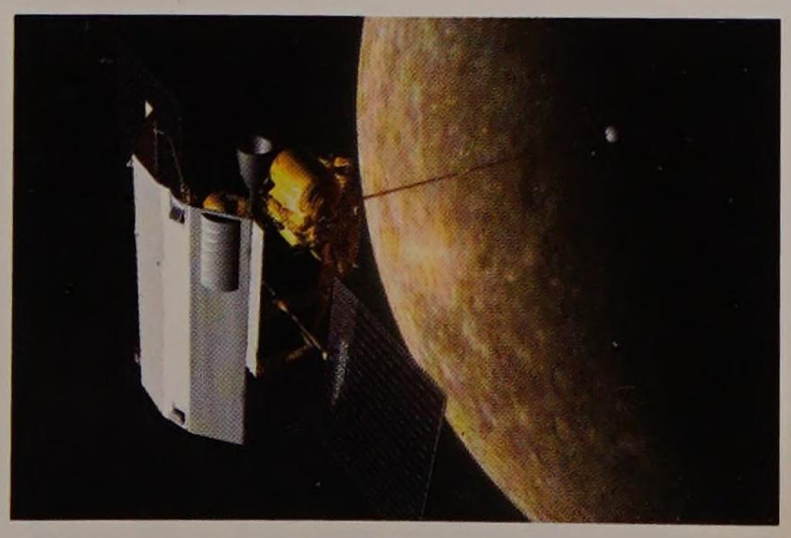
Main mirror for collecting infrared waves



Herschel Space Observatory

Science satellites
The Herschel Space Observatory was a science satellite gathering data in the early 21st century. From 2009 to 2013, its mirror collected long-wavelength infrared radiation from some of the universe's coolest and most distant objects.

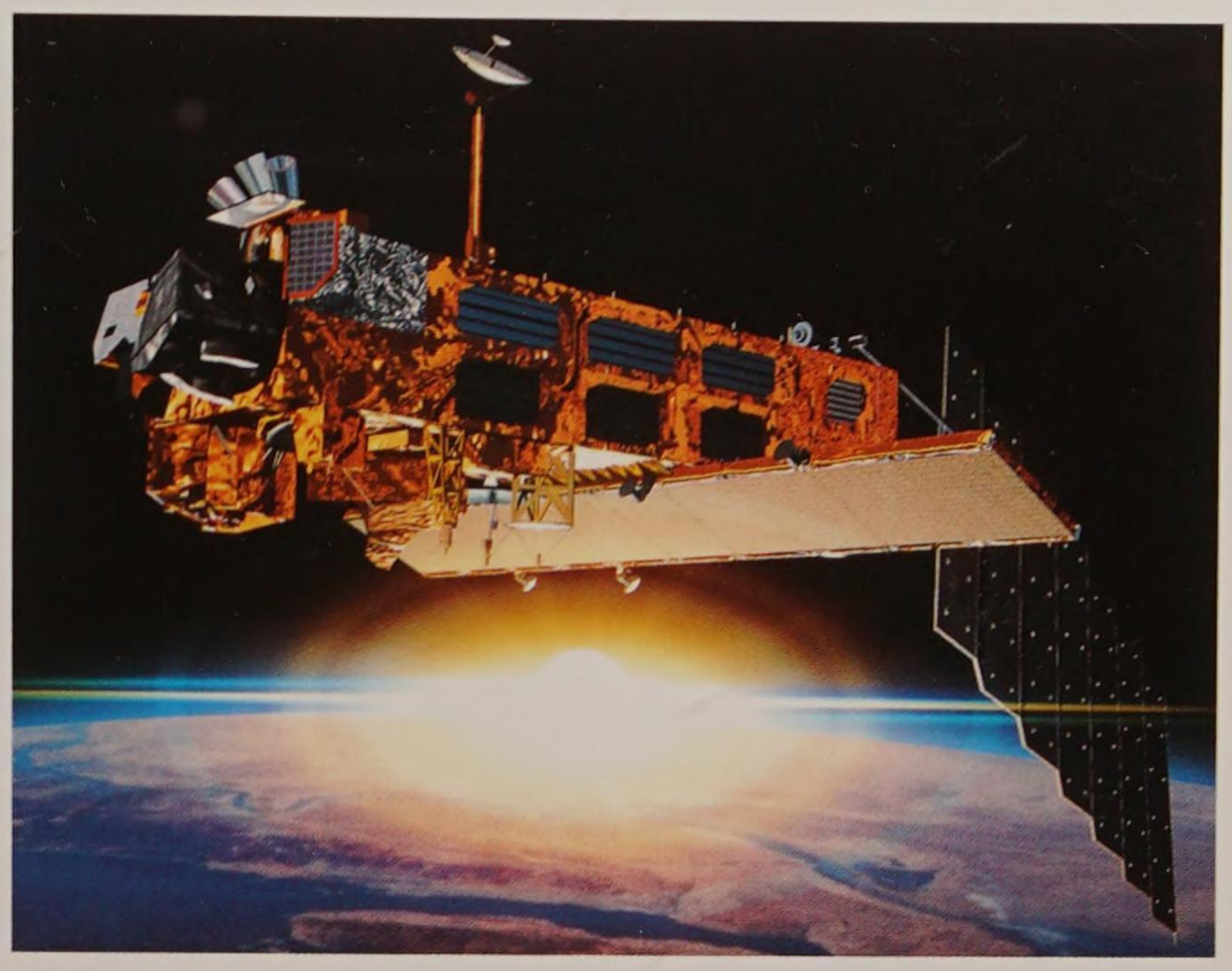
Testing time
New technologies undergo long and extensive testing before use in spacecraft. The probe Deep Space 1 tested 12 new technologies during its three-year mission to asteroid Braille and Comet Borelly. It tested a new form of engine (the ion-propulsion engine), a miniature camera, and computer software that let a craft think and act on its own.



Messenger to Mercury
Launched in 2004, Messenger made its first flyby of Mercury in 2008, before going into orbit around the planet in 2011. Its instruments have mapped Mercury's surface and gathered data on its structure and geological past.

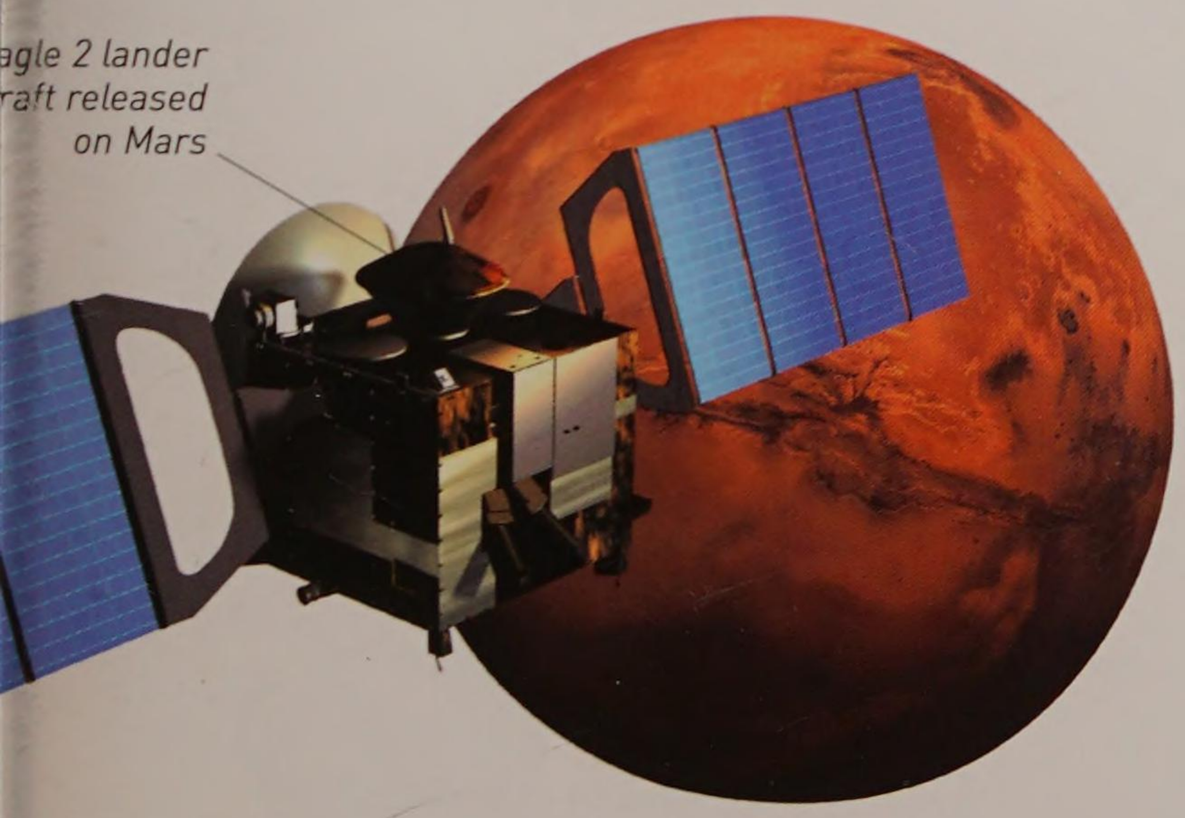
ve on space

e X-ray Multi-Mirror Mission (XMM-Newton) is the most werful orbiting X-ray telescope. Launched in 1999, the XMM-wton helps us understand black holes and the early universe.



Eye on Earth

Envisat was the largest and most advanced Earth observation satellite built in Europe. The size of a truck, it orbited Earth 14 times a day since its launch in March 2002. Its 10 instruments monitored Earth and detected natural or man-made changes on land, in water, or in the air.



agle 2 lander raft released on Mars

ars Express

rs Express moved into orbit around Mars in 2003. It was rope's first planetary mission. From early 2004, its instruments ve been imaging the surface of Mars, mapping its mineral mposition, and studying the Martian atmosphere.

The Genesis undergoes prelaunch preparations

Space engineers wear protective clothing to avoid contaminating the craft with human or Earth dust

Sample return

The Genesis mission, launched in 2001, collected solar wind particles from the Sun and returned them to Earth. Scientists are studying the particles to learn about the way the Sun and the planets formed some 4.6 billion years ago.

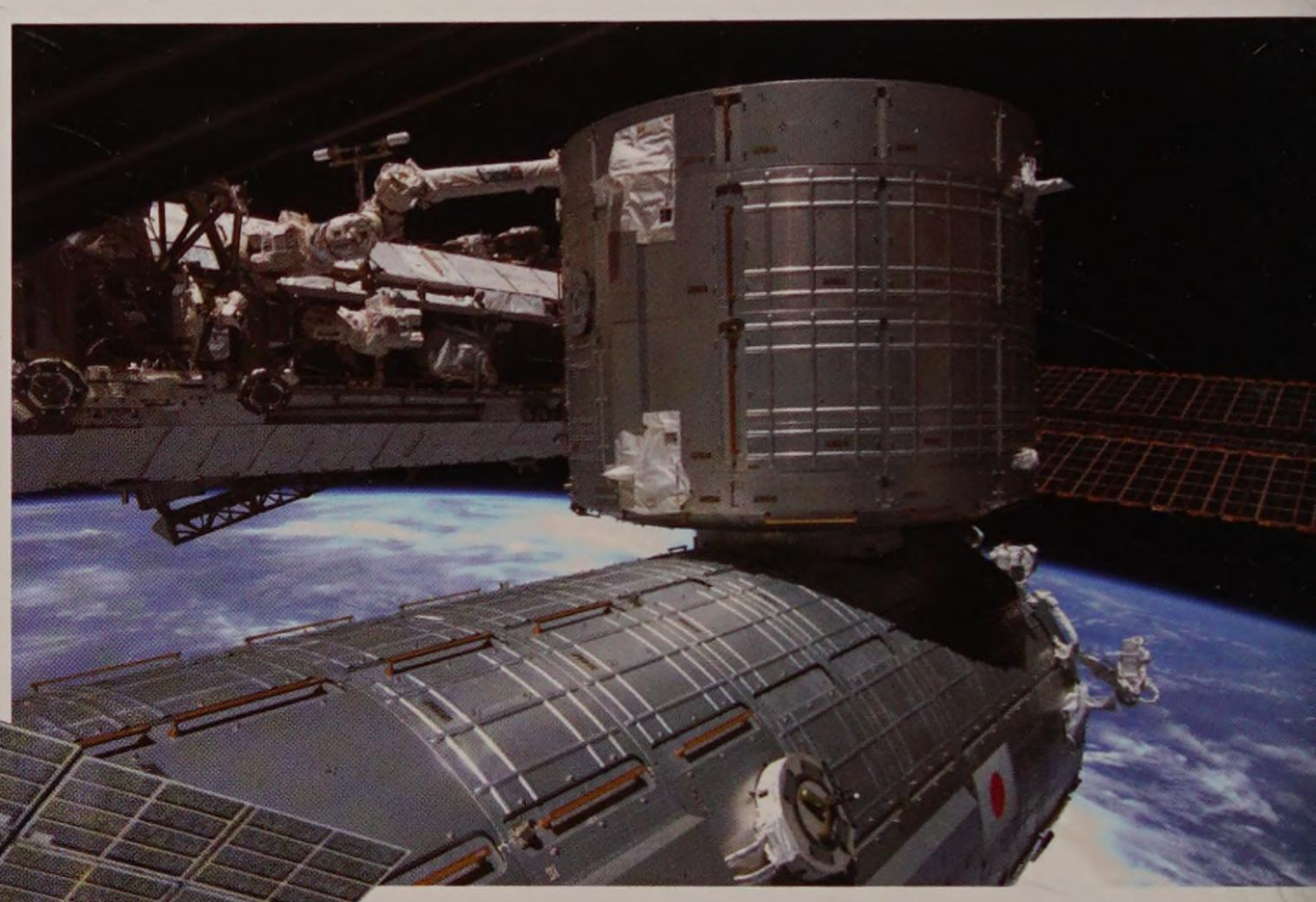
The ISS

In the late 1950s, only a few countries attempted to get into space. The leading space nations, the United States and the Soviet Union, worked to outdo each other. Later, countries joined together to build satellites, space probes, and the International Space Station (ISS).

First crew
On November 2, 2000, the first ISS crew moved in. They were Yuri Gidzenko, William Shepherd, and Sergei Krikalev (left to right). They arrived on a Soyuz craft, but left by space shuttle.

Constructing the station

The ISS was assembled in space between 1998 and 2011. Over 100 parts were fixed together during more than 170 space walks. The ISS came alive when James Newman (below) linked up the first two modules, Zarya and Unity.



Kibo space laborato
The nations currently working on the ISS are t
US, Russia, Canada, Japan, Brazil, a
11 European Space Agency (ESA) countries. Jap
contributed the Kibo space laboratory in 20
The smaller (top) section was fitted first, follow
by the main section, which is the size of a lar
tour bus and the largest single ISS modu

Zarya and Unity
In November 1988, the Russian-built Zarya became the first piece of the ISS to go into space. Control-module Zarya provided power in the early assembly stages. The US connecting-module Unity arrived in December and joined with Zarya.

Mission complete

The ISS is a little bigger than a soccer field. It orbits Earth at 17,500 mph (28,000 kph), and at an altitude of 240 miles (390 km). This view was taken in 2008 by the shuttle Discovery, which delivered the Kibo space laboratory. After the Kibo module, three last parts were added to complete the ISS in 2011.

Columbus laboratory module holds racks of experiments

Kibo module

Jules Verne ATV

Supply craft

Progress is an unmanned, automated Russian craft that, along with the European Automated Transfer Vehicle (ATV), takes supplies to the ISS. The ISS crew unloads the supplies, then fills the craft with waste and unwanted equipment.

rew capsule

tronauts are ferried to and from e ISS inside a Russian Soyuz psule. Once in orbit, the capsule ends two days chasing the ISS fore docking with it. When the air essure between the two craft is ualized, the hatches open and e crew enters the station.

Soyuz capsule is launched to the ISS

Under control

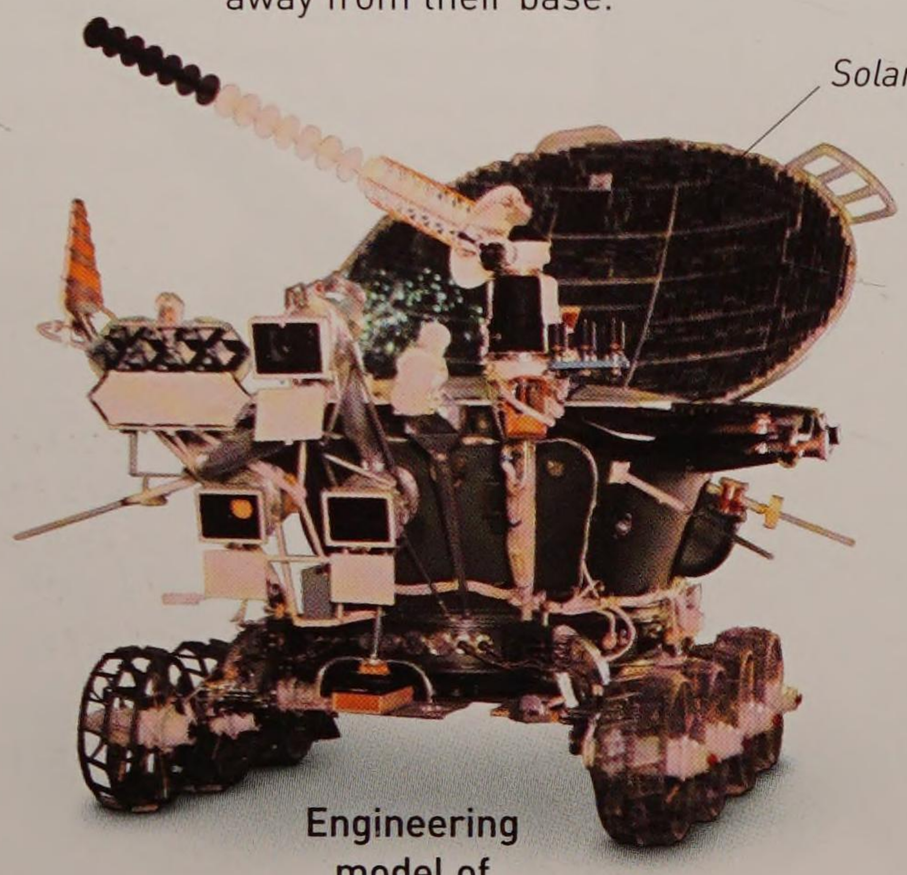
Guests and officials in the Space Mission Control Center in Korolyov, Russia, watch as the ISS crews broadcast in 2008. The astronauts on the screen include Peggy Whitson, who had just completed six-months on the ISS.

Roving around

Robotic spacecraft have landed on six worlds in the solar system. They have touched down on two planets—Mars and Venus; two asteroids—Eros and Itokawa; and two moons—Earth's Moon and Saturn's moon Titan. Some landers stay put, while others rove around.

Rover testing

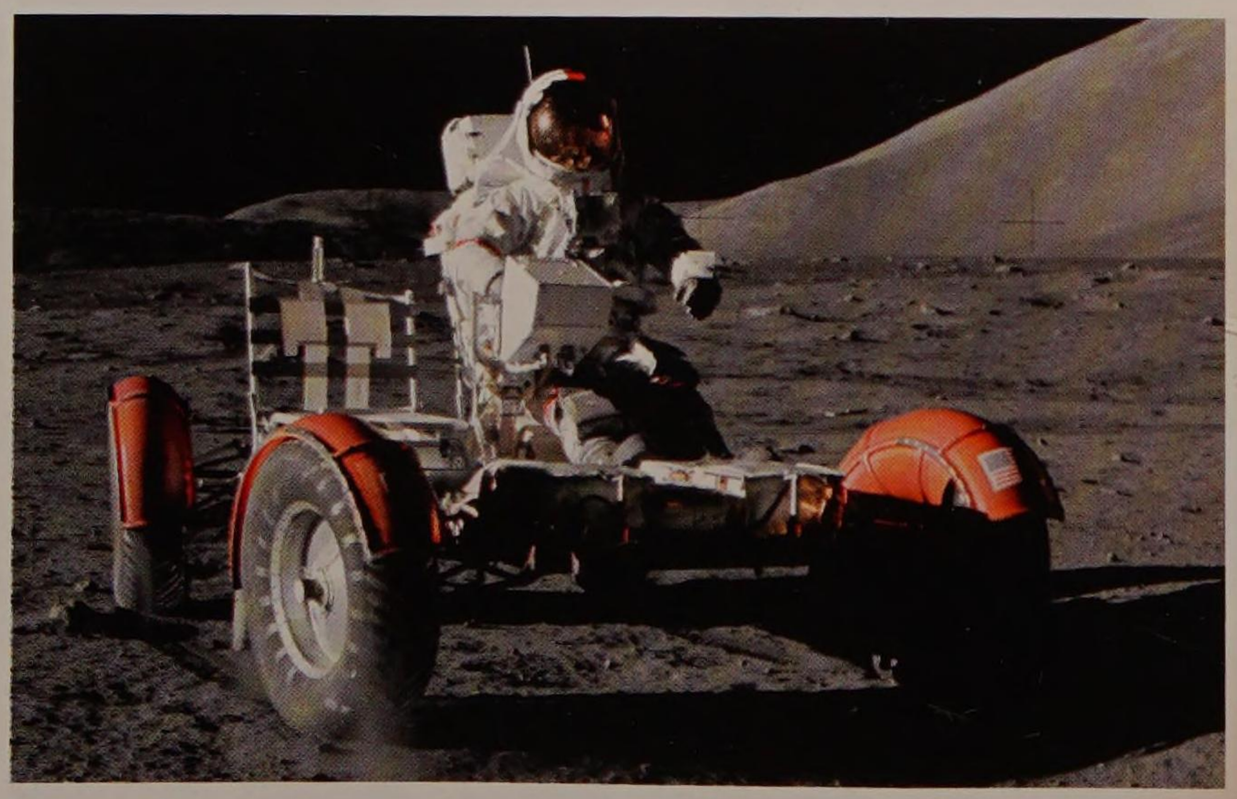
Scientists use engineering models to test thoroughly rovers. NASA is testing this rover (above), which has living modules that allow astronauts to work in a spacesuit-free environment and spend up to 14 days away from their base.



Engineering model of Lunokhod 2

First rovers

Lunokhod 1 and Lunokhod 2 were the first robotic rovers to be sent to another world. Controlled from Earth, they worked on the Moon in the early 1970s, traveling across more than 30 miles (50 km) of its surface between them. In 2013, China's first rover, Yutu, made the first landing on the Moon since 1976.

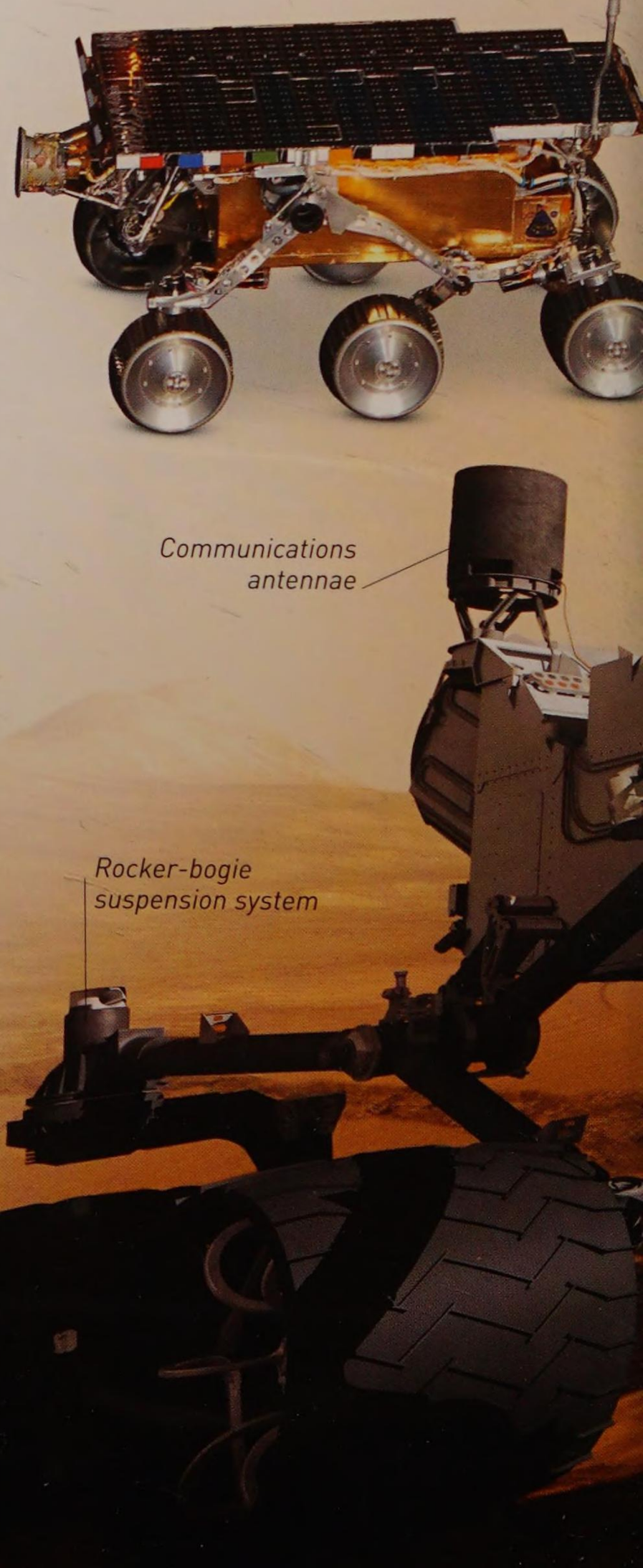


Moon buggy

The Lunar Roving Vehicle, also known simply as the Rover or buggy, was designed to be driven across the Moon. Three were taken to the Moon—one on each of the Apollo 15, 16, and 17 missions, from 1971 to 1972. The Rover allowed astronauts to cover an area 10 times larger than they could on foot.

Sojourner

Sojourner was one of four rovers sent to Mars in 1997. The size of a microwave oven, it roved over 330 ft (100 m) of the floodplain, Ares Vallis.



Mast supports rover's cameras

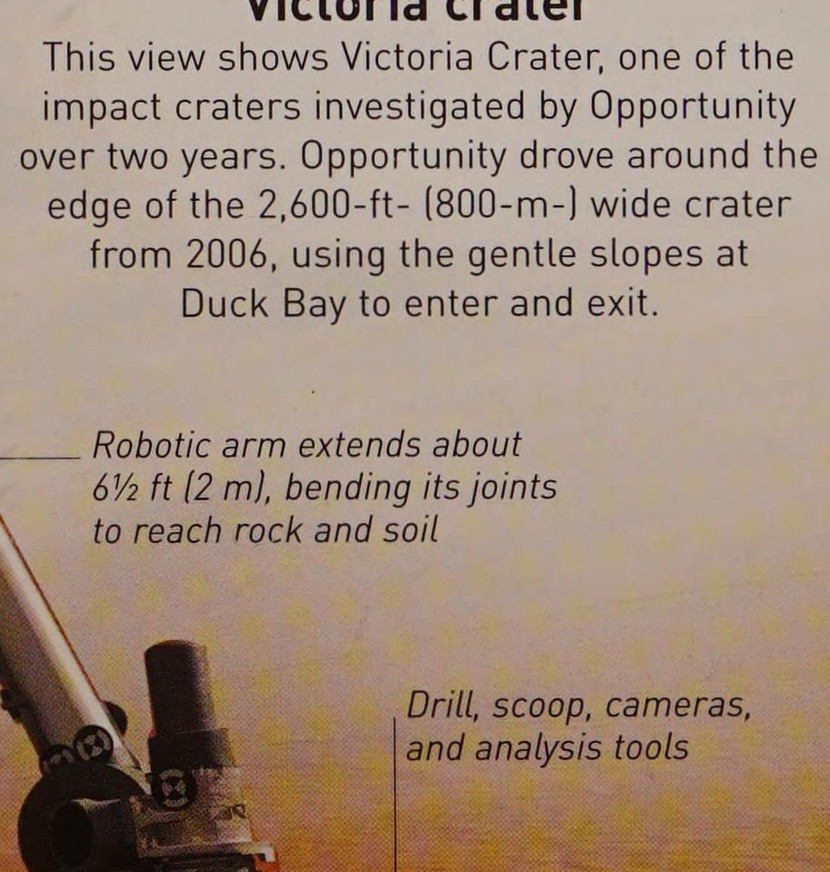
Hinged solar nels unfolded after landing

Each of the wheels has own motor

Opportunity

Twin craft Spirit and Opportunity arrived on opposite sides of Mars in 2004. Although Spirit is no longer working, Opportunity continues to explore. It rolls along at an average speed of ½ in (1 cm) per second, sending back images and results of rock and soil investigations. An articulated arm at the front is equipped with a drill and analysis tools, as well as a camera directly up against the Martian rock and soil.

Unique shape was caused by erosion and downhill movement of crater wall



Victoria crater

This view shows Victoria Crater, one of the impact craters investigated by Opportunity over two years. Opportunity drove around the edge of the 2,600-ft- (800-m-) wide crater from 2006, using the gentle slopes at Duck Bay to enter and exit.

Chemcam zaps rock with its laser

Curiosity

Over time Martian rovers have become more sophisticated. The latest to arrive, Curiosity, landed on Mars in August 2012, and is currently investigating the floor of Gale Crater, a 96-mile- (154-km-) wide impact crater formed more than three billion years ago. Back on Earth, ground controllers send the rover instructions. Collected data are relayed back to Earth directly or via craft.

Robotic arm extends about 6½ ft (2 m), bending its joints to reach rock and soil

Front and rear wheels have individual steering motors

Drill, scoop, cameras, and analysis tools

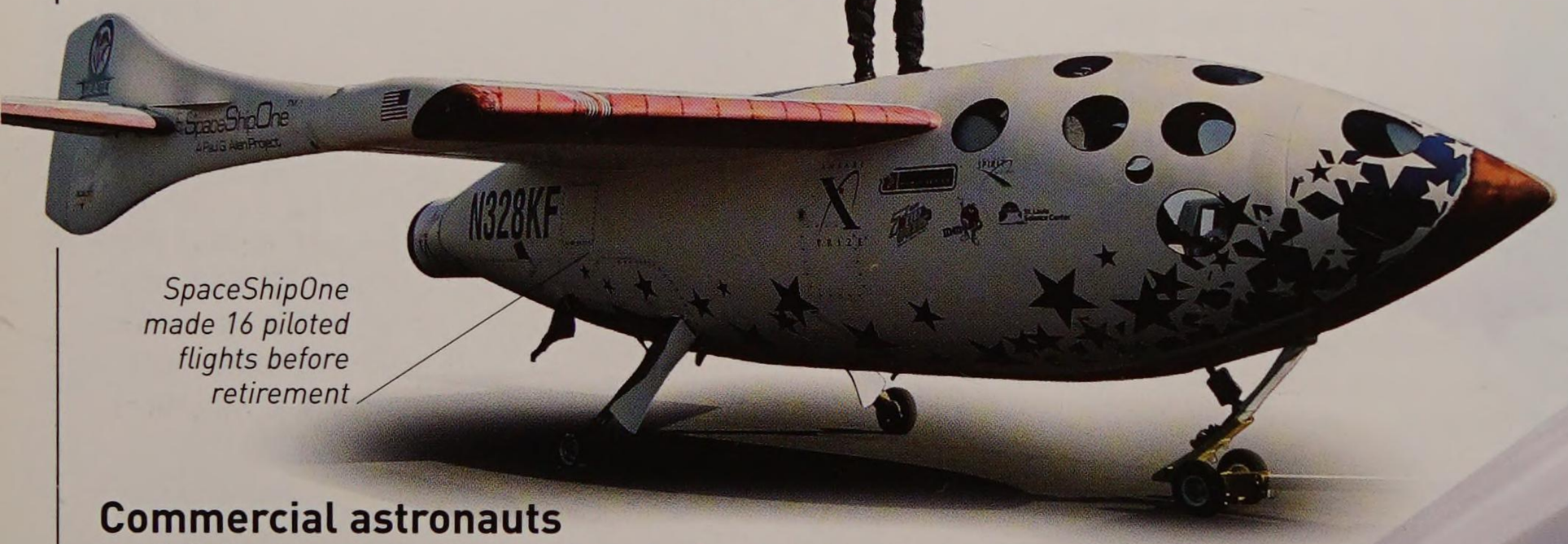
Space tourism

Before the start of the 21st century, the only way to travel into space was as an astronaut. But since 2001, private individuals—the first space tourists—have paid to stay on the International Space Station (ISS). In the future, tourists will even be able to take vacations in space.

First tourists

The first space tourist, American Dennis Tito, made his trip in April 2005. The only female space tourist so far is Iranian-American Anousheh Ansari (above), who stayed on the ISS in 2006.

Brian Binne stands on SpaceShipOne



SpaceShipOne made 16 piloted flights before retirement

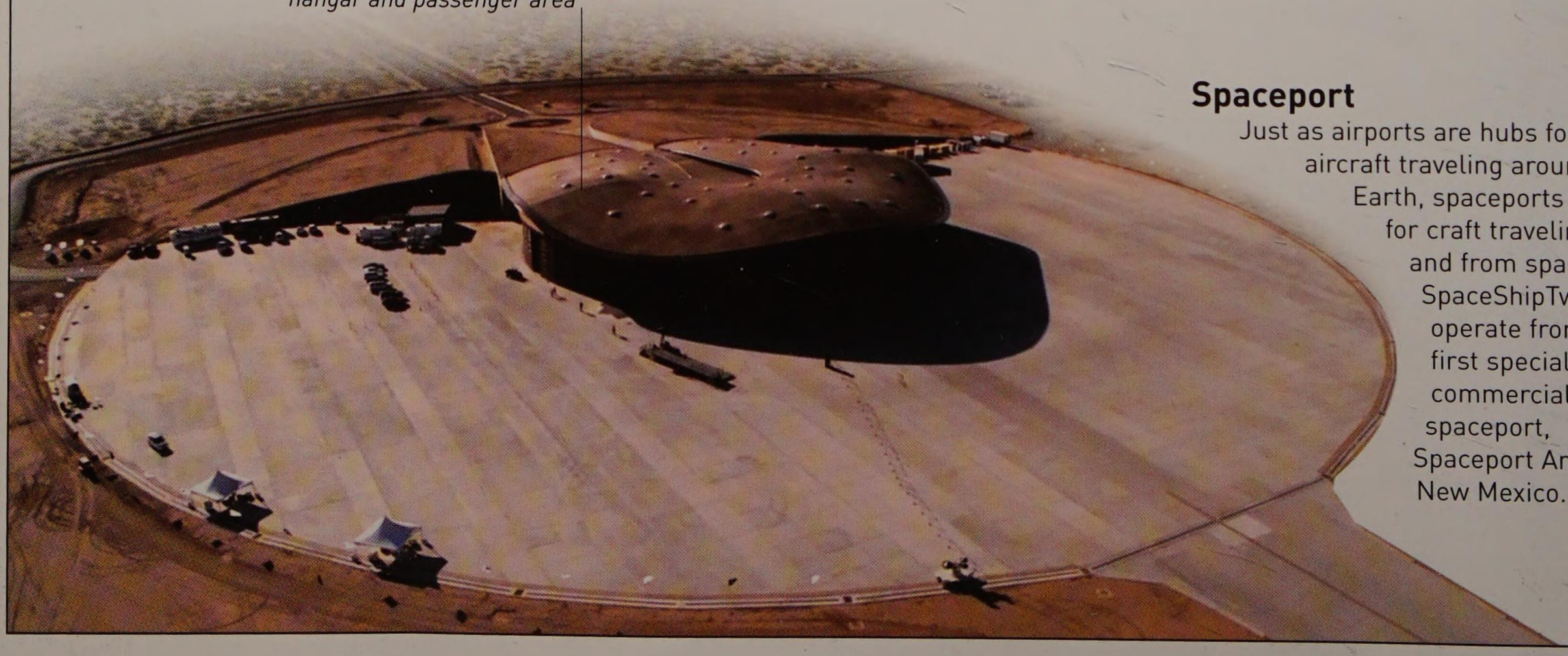
Wingspan of 141 ft (43 m)

Jet engines

Commercial astronauts

Until 2004, astronauts traveled aboard a Russian, American, or Chinese spacecraft. In June that year, Mike Melvill piloted the privately owned SpaceShipOne and became the first commercial astronaut. The only other commercial astronaut, Brian Binnie, piloted SpaceShipOne on October 4, 2004.

Spaceport America's spacecraft hangar and passenger area



Spaceport

Just as airports are hubs for aircraft traveling around Earth, spaceports are for craft traveling to and from space. SpaceShipTwo will operate from the first specially built commercial spaceport, Spaceport America, New Mexico.

SpaceShipTwo

Space tourism companies are already selling tickets for future suborbital flights aboard private craft. One such spacecraft is SpaceShipTwo. On board, six passengers will travel 66 miles (110 km) above Earth, just beyond the edge of space. They will experience six minutes of weightlessness. The trip will last about two and a half hours.

White Knight Two carries SpaceShipTwo

On release, SpaceShipTwo ignites its engine

Space companies

The first seven space tourists paid around $30 million each for their trip. Less costly are zero-gravity flights, where a specially modified aircraft follows a path called a parabolic loop. As the plane falls downward, those inside feel weightless.

pace diving

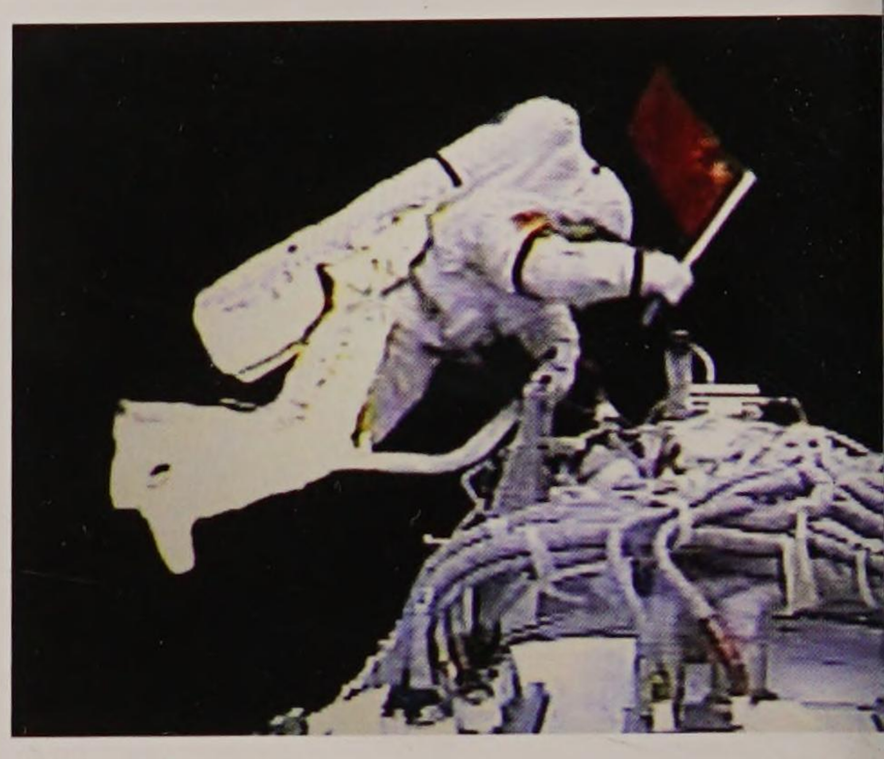
space dive involves leaping from a craft above Earth d free-falling back to the planet. In 2012, Felix umgartner (below) jumped out of a balloon capsule at altitude of 24 miles (39 km) and broke the world cord for a free-fall jump. He also broke the speed of und, traveling at over 800 mph (1,280 kph).

Space hotel

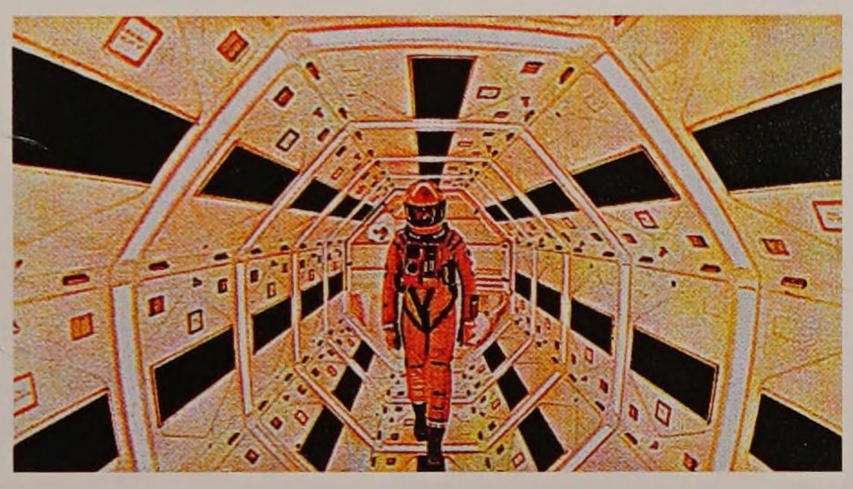
The artwork (right) shows a space hotel placed in Earth's orbit. Future space tourists will stay aboard such privately owned hotels orbiting the Earth. Prototypes have already been tested. Russia launched Genesis 1 in 2006. Once in orbit, it inflated to its full size, 8½ ft (2.6 m) wide. Additional modules can be combined to make a bigger craft.

The way ahead

Space scientists are always looking ahead. As one group works on missions for the next few years, another plans journeys for future decades. They predict that by the mid-21st century, astronauts will have returned to the Moon, and also traveled to the planet Mars. Meanwhile, robotic craft will study new targets. Today's search for Earthlike planets may open up whole new areas so far not dreamed of.

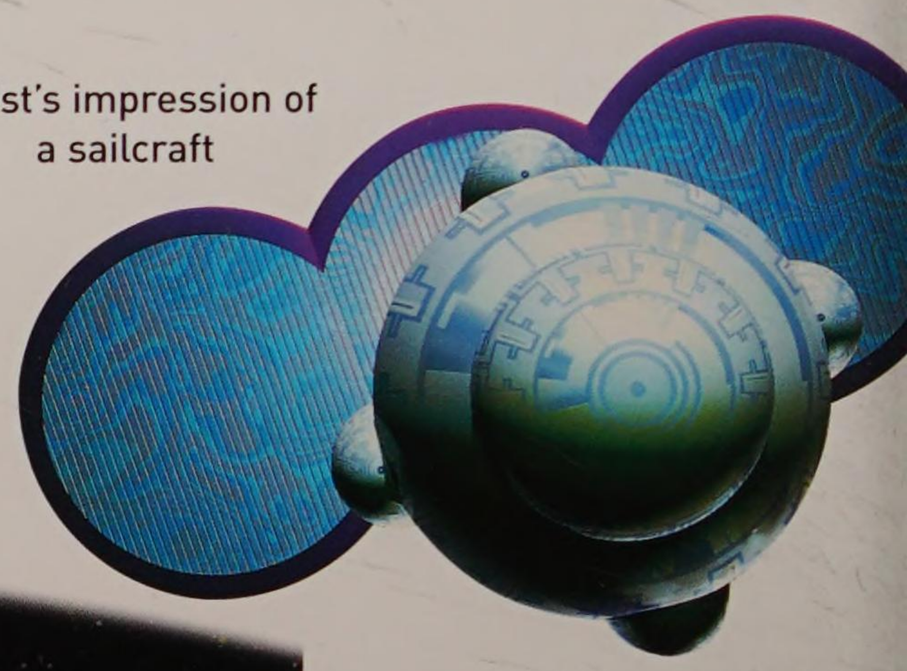


China in space
Astronaut Zhai Zhigang waves his nation's flag during China's first space walk in 2008. When China launched its first astronaut in 2003, it became only the third country to send people into space. Since then, China has successfully sent two orbiters to the Moon.



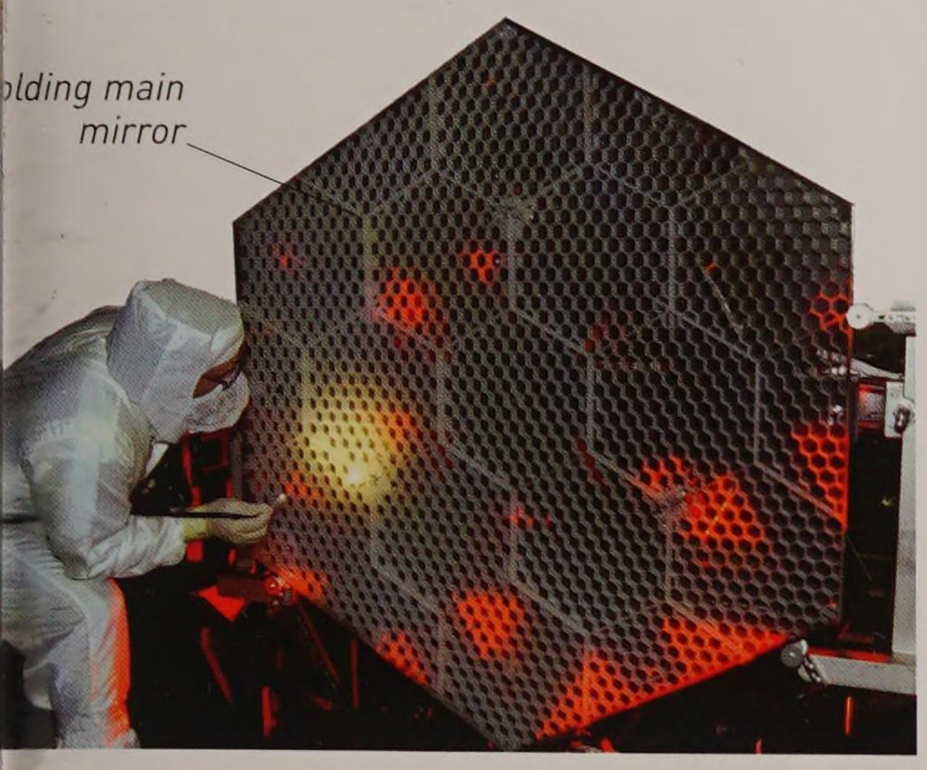
Future predictions
Predicting the future is not easy. When the film *2001: A Space Odyssey* (shown here) was released in 1968, it was incorrectly believed that space travel would be a regular part of early 21st-century life.

Artist's impression of a sailcraft



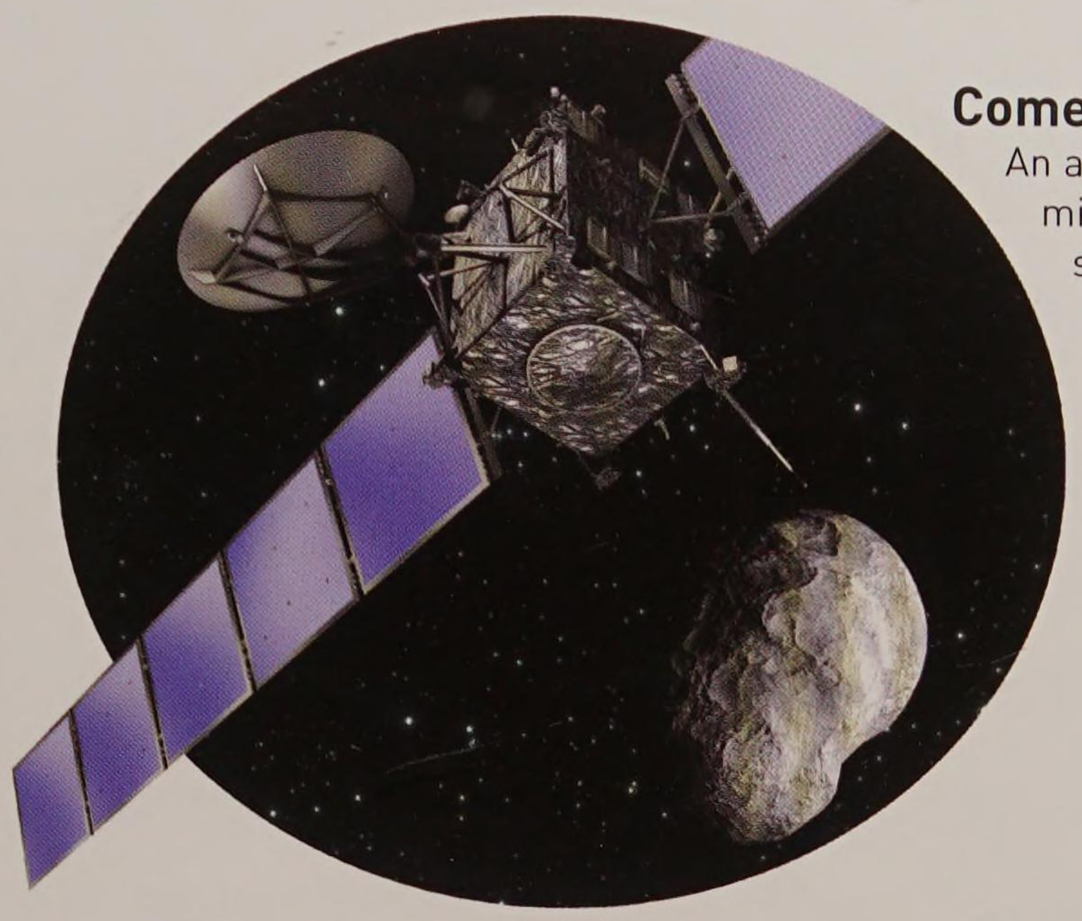
Sailcra
Scientists are investigatin forms of propulsion th could take craft beyond th solar system. One approac is to sail across spac using the pressure sunlight on the sails propel a craft. A sailcra illustration is shown abov

Orion craft
This artist's impression shows the Orion spacecraft on its way to the International Space Station (ISS). Orion will take over the space shuttle's role of carrying crew and cargo to the station.



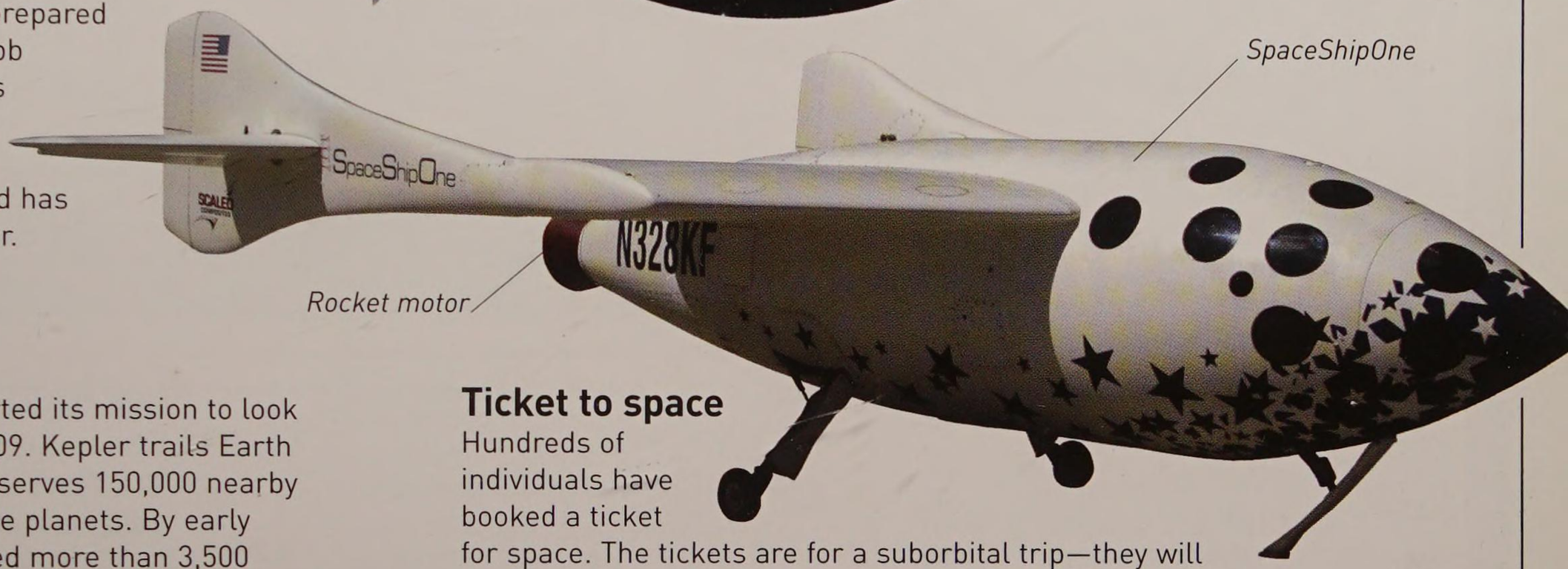
pace telescope

mirror segment of the James
ebb Space Telescope is prepared
r a 2018 launch. The Webb
elescope is larger than its
redecessor Hubble, works
infrared (Hubble is a
sible-light telescope), and has
n innovative folding mirror.



Comet chaser

An ambitious space mission sent the Rosetta spacecraft flying for 10 years to reach the Comet Churyumov-Gerasimenko in May 2014. Rosetta will travel with the comet for two years as it heads toward the Sun.

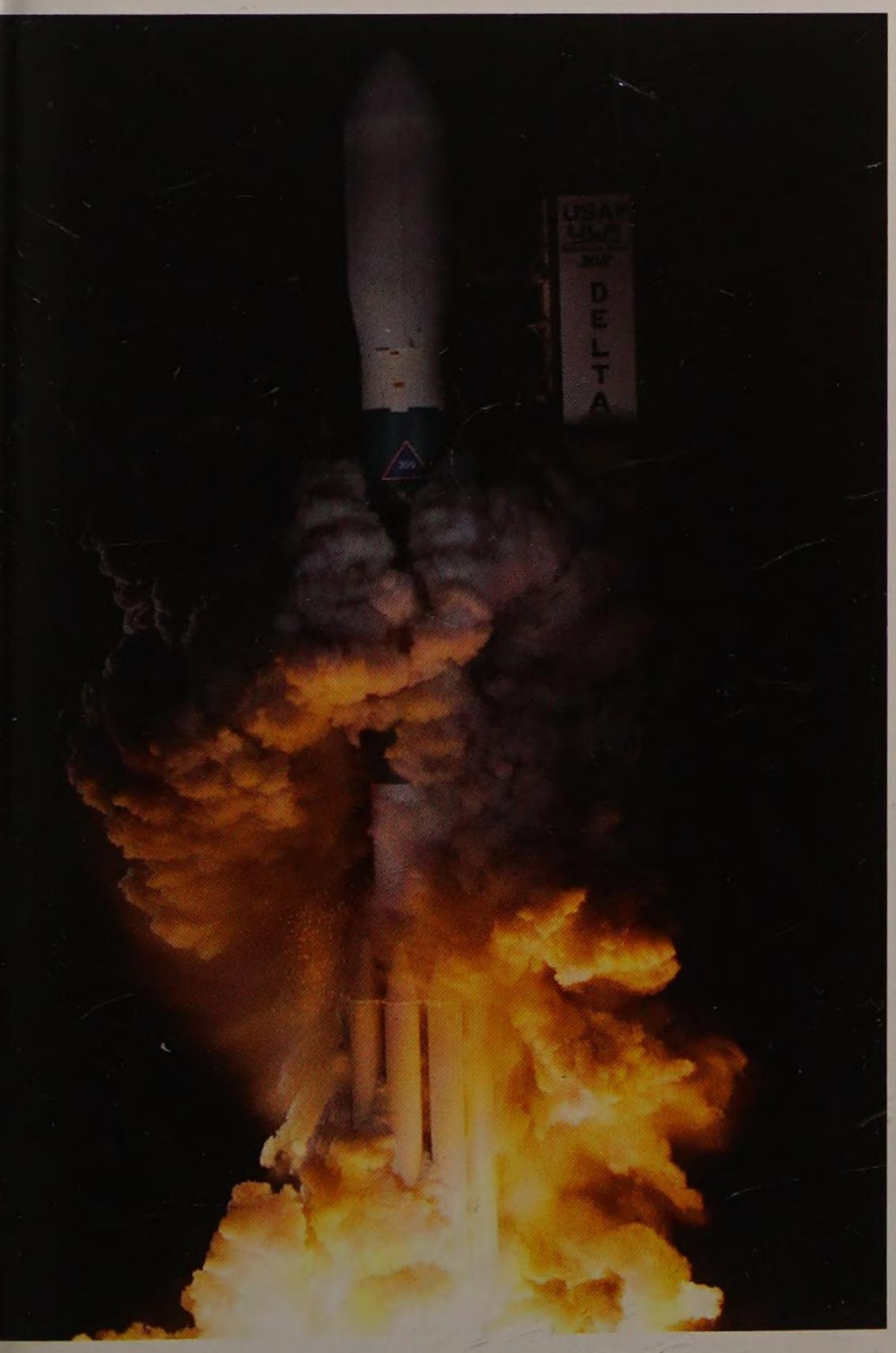


Ticket to space

Hundreds of individuals have booked a ticket for space. The tickets are for a suborbital trip—they will reach space but not go into orbit around Earth. The craft to carry them are built and being tested. In 2004, SpaceShipOne, the first privately owned spacecraft completed its first flight. Its successor SpaceShipTwo will carry passengers to space.

nyone there?

he Kepler spacecraft started its mission to look
r Earthlike planets in 2009. Kepler trails Earth
s it orbits the Sun and observes 150,000 nearby
unlike stars that may have planets. By early
014, Kepler had discovered more than 3,500
lanets, a few hundred of which are Earth-sized.

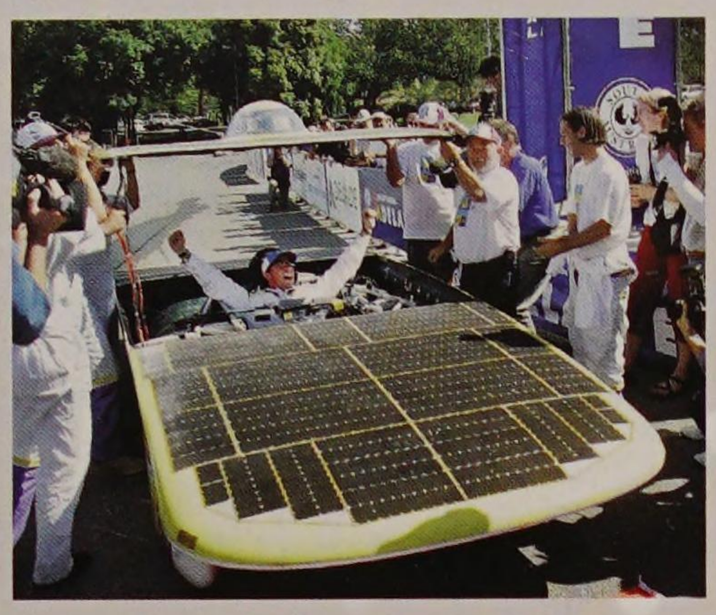


Next stop Mars

Both the US and China are developing craft that will send astronauts to Mars in the mid-21st century. A round trip would take about a year and a half if the astronauts spent just three weeks on the planet.

Did you know?

FASCINATING FACTS



Victory for solar car Nuna

Space technology can be used to improve Earth designs. In 2001, a solar car called Nuna used European space technology to win the World Solar Challenge. Nuna drove the 1,870-mile (3,010-km) race in Australia in just 32 hours, 39 minutes.

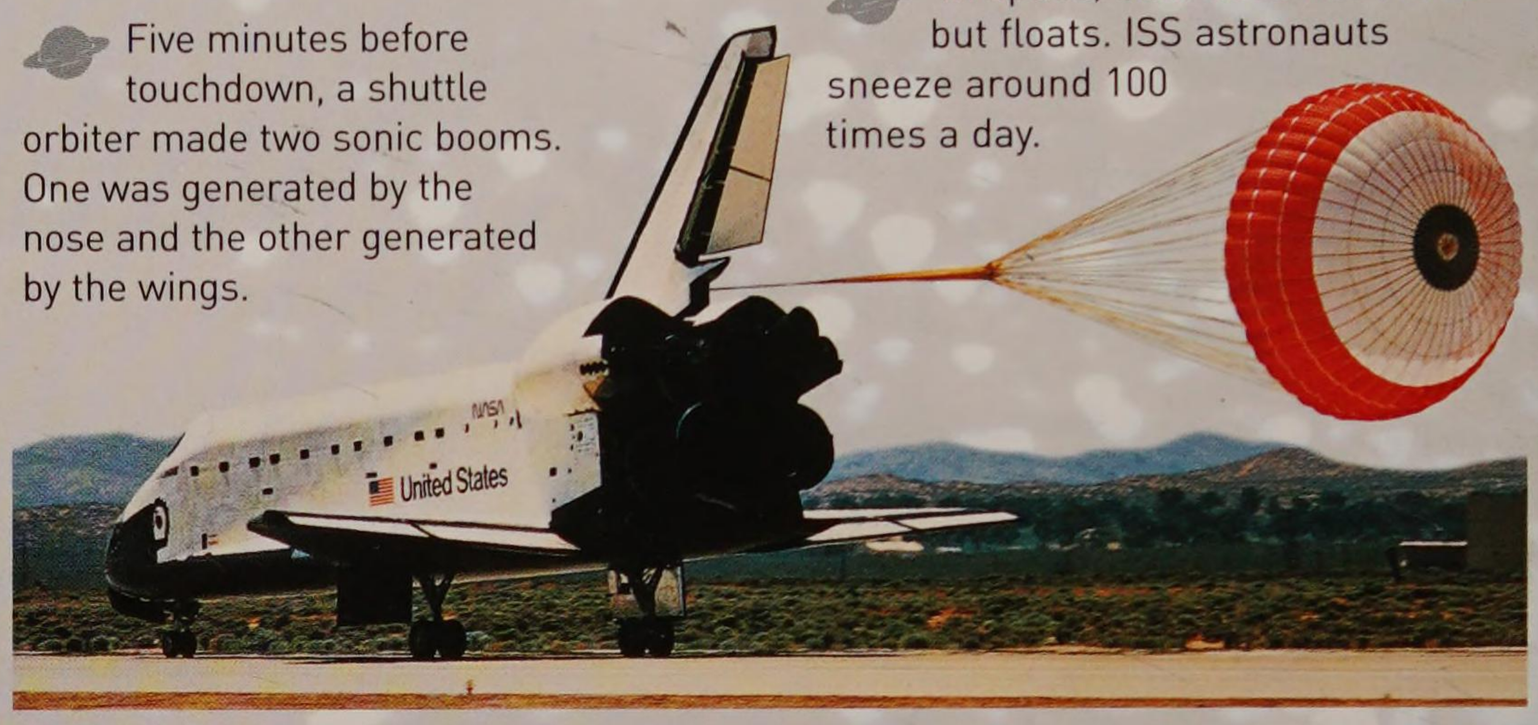
In 1999, Gene Shoemaker became the first person to be "buried" on the Moon. His ashes were aboard Lunar Prospector when it was launched on January 6, 1998.

Experiment to test the effects of weightlessness

There are plans to send astronauts farther into space. For this, scientists are investigating the long-term effects on the human body of living without gravity. One experiment required volunteers to lie at an angle of 6° for three months.

Cassini, which has been orbiting Saturn since 2004, is carrying a DVD with 616,400 signatures of Individuals from 81 nations.

Five minutes before touchdown, a shuttle orbiter made two sonic booms. One was generated by the nose and the other generated by the wings.



The drag chute slowed down the space shuttle orbiter as it landed

By 2009, the shuttle fleet had notched up 131 flights and over 18,500 orbits of Earth. Between them, the fleet docked to the International Space Station (ISS) 23 times.

NASA stayed in touch with Pioneer 10, launched for Jupiter in 1972, for over 30 years. It was built for a 21-month mission, but its last signal was received in 2003.

When the Pathfinder probe landed on Mars in 1997 it was inside a giant ball of airbags for protection. After bouncing on the surface 15 times, three panels of the probe opened to allow the Sojourner Rover to explore the surface.

Half of all astronauts vomit during their first days in space—a supply of air-sickness bags is vital.

In space, dust does not settle but floats. ISS astronauts sneeze around 100 times a day.

The European Space Agency held a competition to name the four Cluster satellites launched in 2000 to study the Sun and the Earth's magnetic field. The winner chose the names Tango, Salsa, Samba, and Rumba, because the satellites would seem to be dancing in space.

The Hubble Space Telescope's instruments can hold still on a subject and deviate less than the width that a human hair would appear from 1 mile (1.6 km) away.

In 1966, Eugene Cernan, from Gemini IX, did a space walk of 2 hours, 7 minutes, beating the previous record of 36 minutes. During this time, the craft had orbited Earth, so Cernan has the honor of being the first man to walk around the world.

View of Martian landscape from Pathfinder

QUESTIONS AND ANSWERS

New Horizons probe to Pluto

Q What is the farthest a spacecraft has traveled?

A The New Horizons spacecraft covered a distance of about 3 billion miles (5 billion km) when it was launched to Pluto in 2006.

Q What sort of temperatures occur in space? Is it hot or cold?

A In space, temperatures—depending on whether you are in sunlight or in shadow—range between –150°F and 250°F (–101°C and 121°C).

Q What caused the Challenger and Columbia space shuttle disasters?

A The day of the Challenger launch in 1986 was cold, and this affected a seal on one of the solid rocket boosters. Fuel escaped and ignited 73 seconds after launch, blowing the shuttle apart. Shuttle flights were suspended for two years while safety was reviewed. The 2003 disintegration of Columbia was caused by hot gas entering the shuttle's wing through a hole. The hole had been made at launch 16 days earlier by a piece of foam that peeled off the fuel tank.

Pieces of Mir blaze through the Earth's atmosphere

Q How much is a ticket to space?

A The first space tourist, California millionaire Dennis Tito, paid about $23 million for an eight-day trip to the International Space Station (ISS) in April 2001. Charles Simonyi went to the ISS twice at a total cost of $60 million. But you can reserve a ticket on a commercial suborbital flight for around $250,000.

Q Is life in space completely silent? Is it quiet in a spacecraft, too?

A Space is silent because there is no air through which sound can travel. On an extra vehicular activity (EVA), astronauts cannot hear each other, even if they are side by side. They communicate by radio.

Space tourist Dennis Tito

Record breakers

LONGEST SINGLE STAY IN SPACE
In 1995, Russian Valeri Poliakov returned to Earth after 438 days, 17 hours, 58 minutes, and 16 seconds in space.

MOST TIME SPENT IN SPACE
Sergei Krikalev holds the record for time spent in space, at 803.4 days.

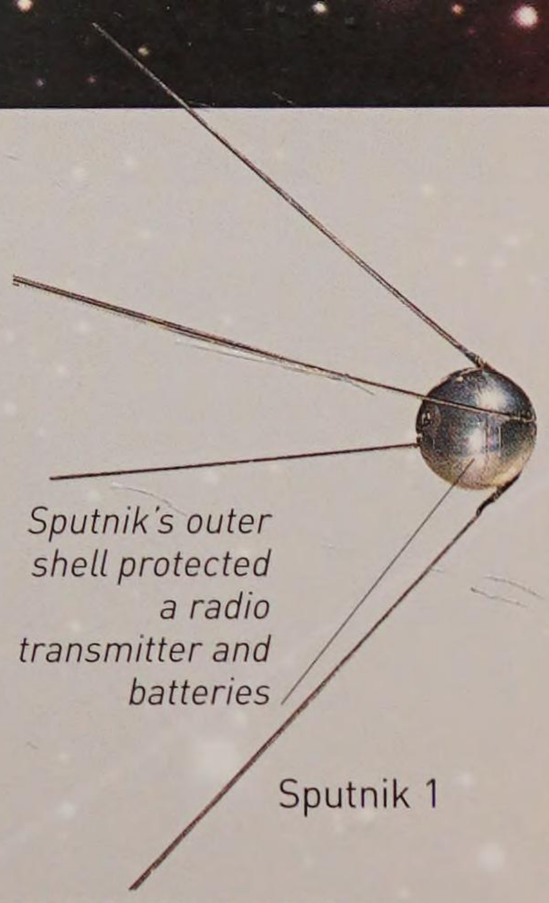
LONGEST EXTRA VEHICULAR ACTIVITY
In March 2001, Susan Helms and Jim Voss spent 8 hours, 56 minutes working outside on the ISS.

OLDEST SPACE TRAVELER
In 1998, astronaut John Glenn became the oldest space traveler, at 77.

FIRST COMMERCIAL ASTRONAUT
In 2004, Mike Nevill became the first commercial astronaut when he piloted private spacecraft SpaceShipOne.

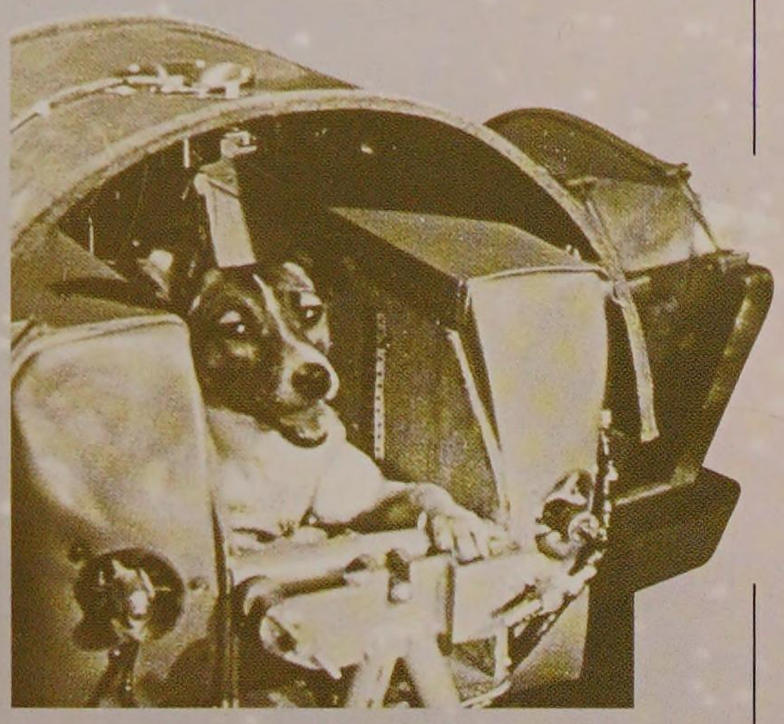
Timeline

Ever since Sputnik went into orbit in 1957, the story of space exploration has advanced at a fast and furious pace. Below is a timeline of some of the most significant achievements.



Sputnik 1

OCTOBER 4, 1957
Soviet Union puts Sputnik 1, the world's first artificial satellite, into Earth orbit.



Space dog Laika aboard Sputnik 2

NOVEMBER 3, 1957
The first living creature, a Soviet dog named Laika, orbits Earth in Sputnik 2.

JANUARY 2, 1959
Soviet probe Luna 1 becomes the first craft to leave Earth's gravity.

SEPTEMBER 13, 1959
Luna 2 is the first craft to land on another world when it crash-lands on the Moon.

OCTOBER 10, 1959
Soviet Luna 3 spacecraft returns the first pictures of the Moon's far side.

APRIL 12, 1961
Soviet cosmonaut Yuri Gagarin becomes the first person to travel into space.

Yuri Gagarin

JULY 10, 1962
US launches Telstar 1, the first realtime communications satellite.

JUNE 16, 1963
Soviet cosmonaut Valentina Tereshkova becomes the first woman in space.

MARCH 18, 1965
Soviet cosmonaut Alexei Leonov makes the first space walk. He is secured to Voskhod 2 by a tether.

JULY 15, 1965
US probe Mariner 4 completes the first successful Mars flyby.

FEBRUARY 3, 1966
Soviet craft Luna 9 becomes the first to land successfully on the Moon.

DECEMBER 24, 1968
US craft Apollo 8 is the first manned craft to leave Earth's gravity and orbit the Moon.

JULY 20, 1969
The US astronaut Neil Armstrong is the first to walk on the Moon, Buzz Aldrin the second.

SEPTEMBER 20, 1970
Soviet probe Luna 16 lands on the Moon. It will be the first craft to collect soil and return it to Earth.

Neil Armstrong's reflection can be seen in Buzz Aldrin's visor

Buzz Aldrin on the Moon, 1969

NOVEMBER 17, 1970
The first wheeled vehicle on the Moon, Lunokhod 1, starts its work.

APRIL 19, 1971
Launch of the first space station, Soviet Salyut 1.

DECEMBER 19, 1972
Return to Earth of Apollo 17, the sixth and last manned mission to the Moon.

MARCH 29, 1974
US spacecraft Mariner 10 makes the first flyby of Mercury.

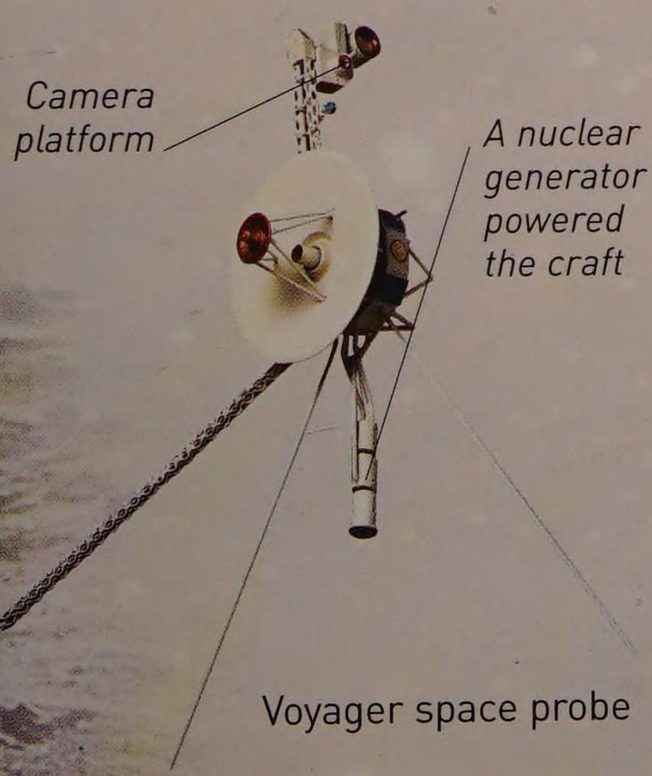
OCTOBER 22, 1975
Soviet craft Venera 9 transmits the first images from Venus.

JULY 20, 1976
The US probe Viking 1 becomes the first craft to land on the planet Mars.

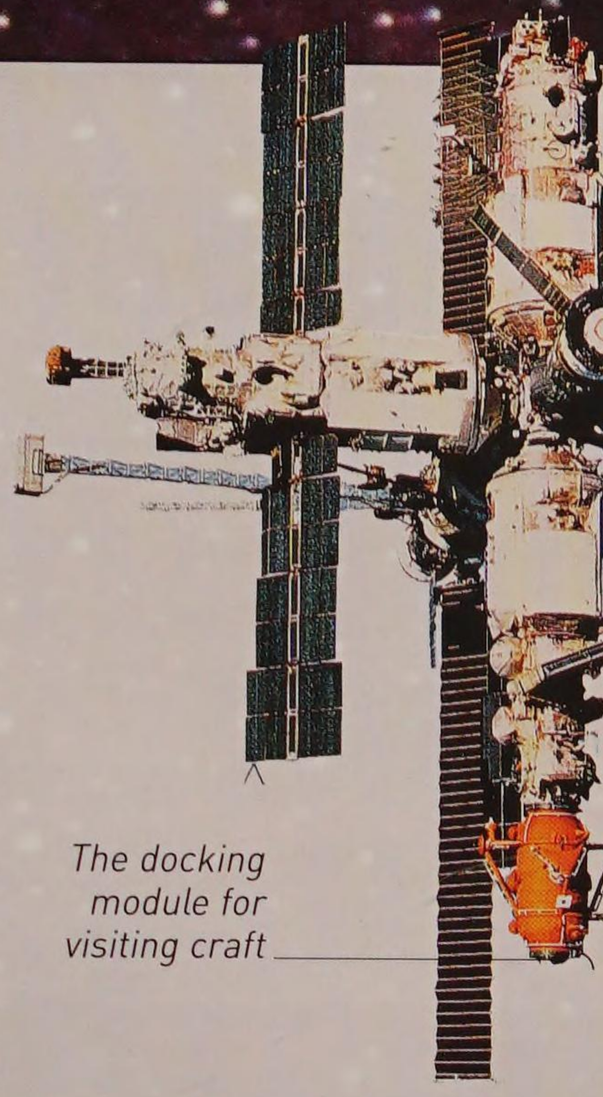
SEPTEMBER 1, 1979
The US probe Pioneer 11 makes the first flyby of the planet Saturn.

APRIL 12, 1981
Launch of the first reusable space vehicle, space shuttle Columbia.

Columbia, the first shuttle in space



Voyager space probe



FEBRUARY 20, 1986
The first module of the Soviet space station, Mir, is launched into orbit.

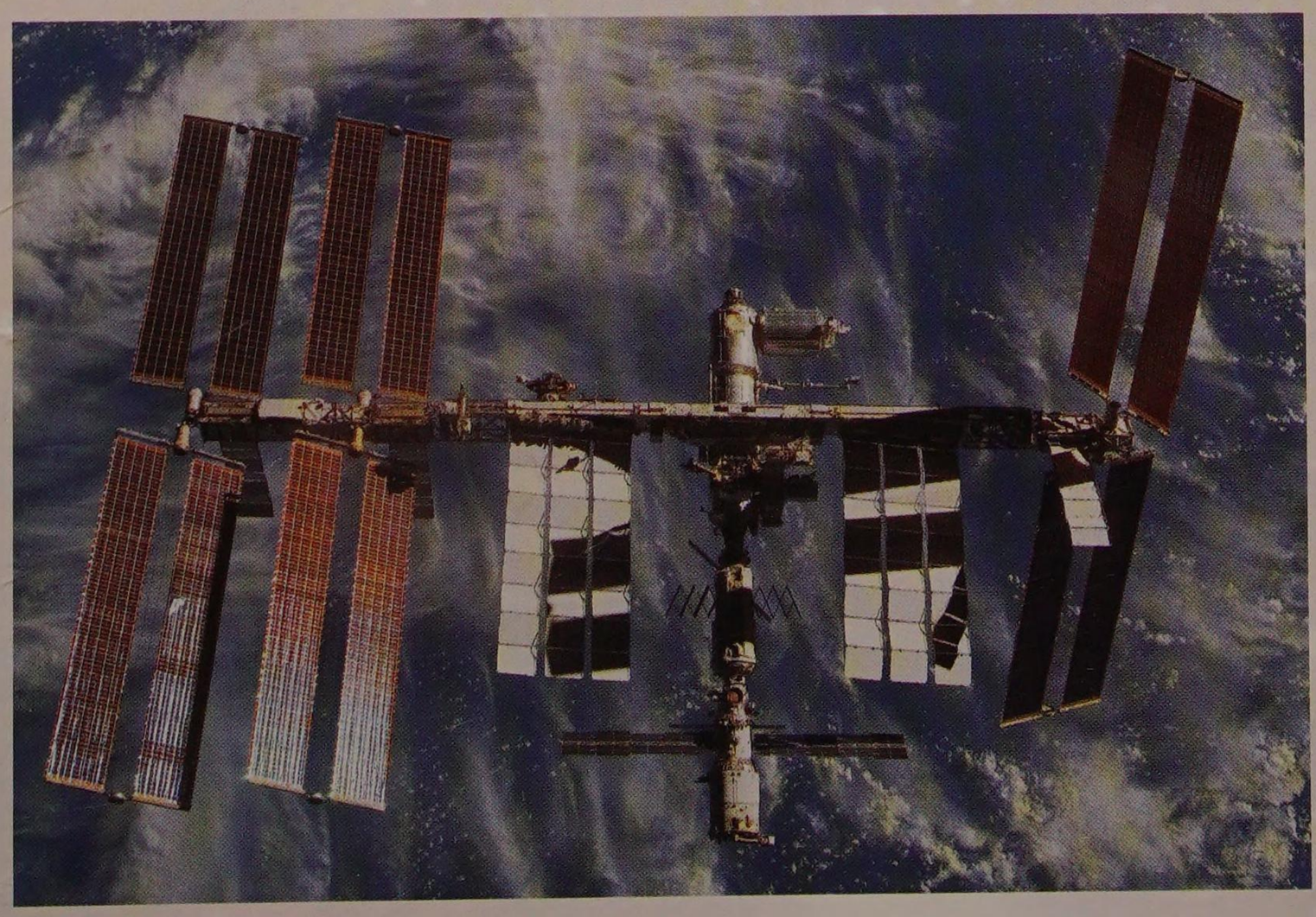
MARCH 13, 1986
Giotto, a European probe, makes a flyby of Halley's Comet.

AUGUST 24, 1989
Voyager 2 makes the first flyby of Neptune.

APRIL 24, 1990
Space Shuttle Discovery launches the Hubble Space Telescope.

OCTOBER 29, 1991
US probe Galileo makes the first flyby of an asteroid.

NOVEMBER 20, 1998
Zarya, the first part of the ISS, is launched.



International Space Station (ISS)

NOVEMBER 2, 2000
The first crew boards the ISS.

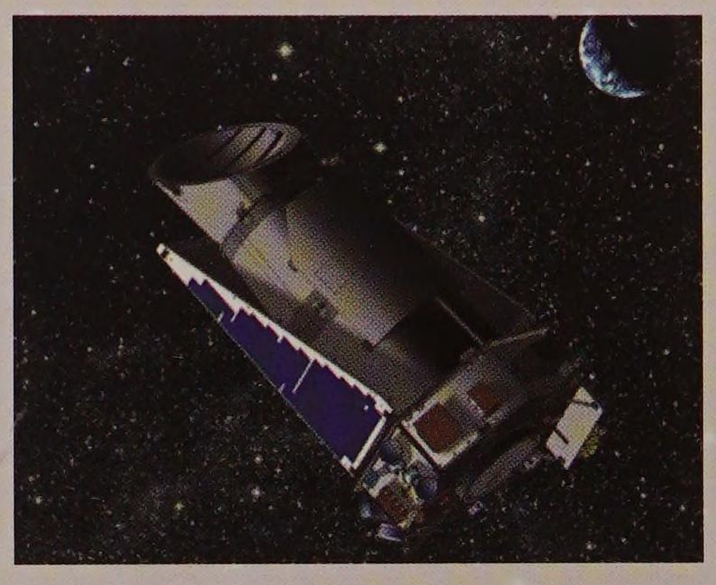
FEBRUARY 12, 2001
Near Earth Asteroid Rendezvous (NEAR) lands on an asteroid.

JANUARY 4, 2004
A rover named Spirit arrives on Mars.

MARCH 6, 2009
The Kepler space telescope launched to look for alien life.

Space station Mir

JULY 21, 2011
Space Shuttle Atlantis completes the 135th and final shuttle mission.



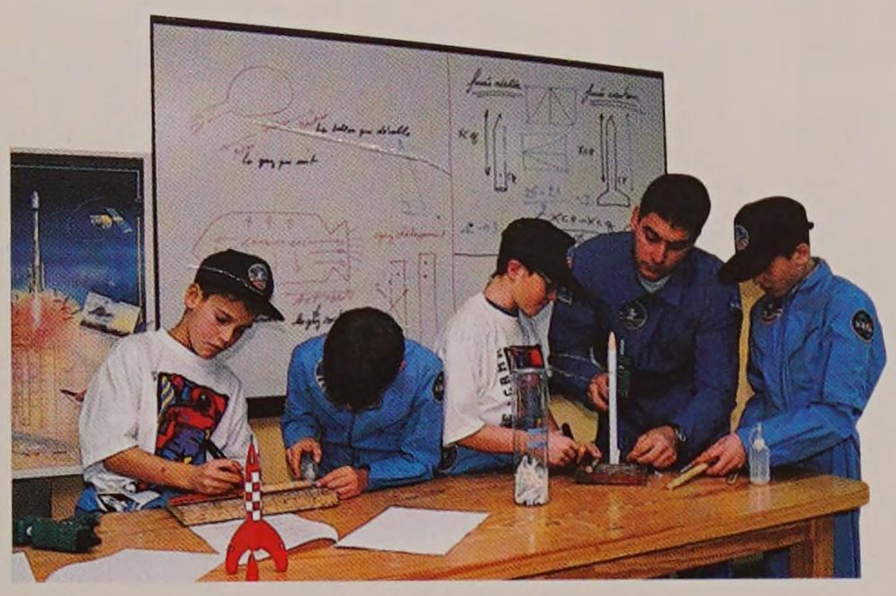
Kepler space telescope

AUGUST 6, 2012
The rover Curiosity lands on Mars.

JANUARY 20, 2014
European craft Rosetta continues to make its way to its main target, Comet Churyumov-Gerasimenko.

Find out more

There are many ways to learn about space. Books, TV, newspapers, and the internet are all good sources of information, as are space centers. Here, visitors can share the experiences of an astronaut and see the craft that explore space for us.



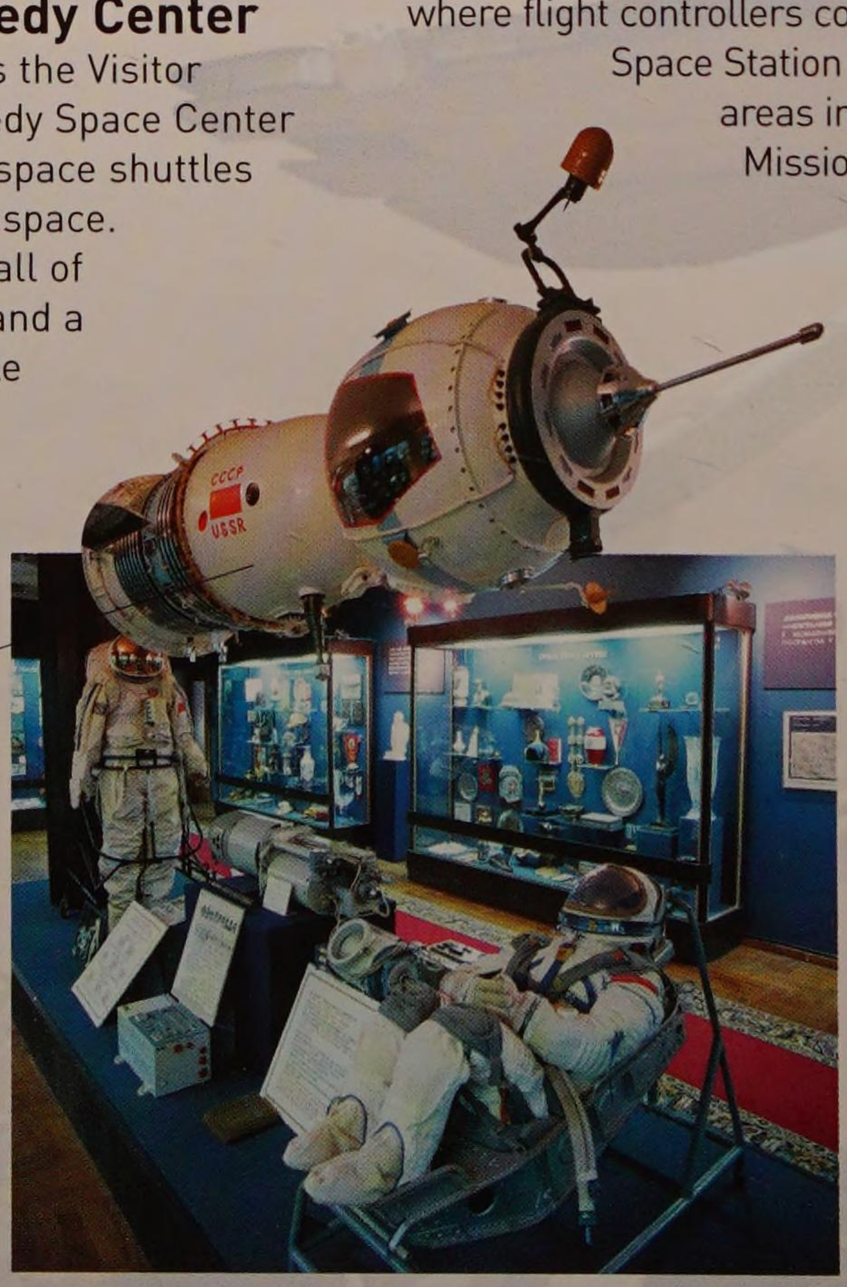
Transinne Space Center
These children are doing experiments at the Euro Space Center in Transinne, Belgium. Exhibits include a big display on the Columbus Laboratory, the European contribution to the International Space Station. Visitors can also try out space simulators used to train astronauts.

Space rockets

Kennedy Center
This picture shows the Visitor Complex at NASA's Kennedy Space Center in Florida, from where rockets and space shuttles launched American astronauts into space. Its exhibits include the Astronaut Hall of Fame, the Apollo-Saturn V Center, and a rocket launch site. The space shuttle Atlantis has also been opened for public display.

Mission Control, Houston
The National Aeronautics and Space Administration's (NASA's) Johnson Space Center, in Houston, Texas, is where astronauts are trained, and from where flight controllers coordinate with them when on the International Space Station (ISS). Space Center Houston's exhibition areas include Astronaut and ISS galleries and a Mission Control room tour.

Spacecraft at Star City



Star City, Moscow
Exhibits telling the story of the Russian manned flight program can be seen in the museum of the Yuri Gagarin Cosmonaut Training Facility at Star City, an hour from Moscow.

OTHER PLACES TO VISIT

ROSE CENTER FOR EARTH AND SPACE, AMERICAN MUSEUM OF NATURAL HISTORY, NEW YORK CITY
• A space center featuring Scales of the Universe and the Hayden Planetarium.

SPACE CENTER, HOUSTON, TEXAS
• See astronauts train, land a shuttle, and take a tour of NASA.

SMITHSONIAN NATIONAL AIR AND SPACE MUSEUM, WASHINGTON, D.C.
• Home of a original space hardware, including the Apollo 11 module.

EXPLORING SPACE ON THE WEB

Space is an exciting topic to explore on the internet. Organizations such as the National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA) have fascinating websites. Below are a few subjects and websites you may want to investigate further.

Exploring space

To find out more about the planets, such as Mars (above), search on the ESA and NASA sites. For the latest images from deep space, look on the Hubble Space Telescope website: **hubblesite.org**

European program

News of European Space Program (ESA) projects and activities can be found at:

- ESA homepage **www.esa.int/ESA**
- ESA activities pages **www.esa.int/Our_Activities**

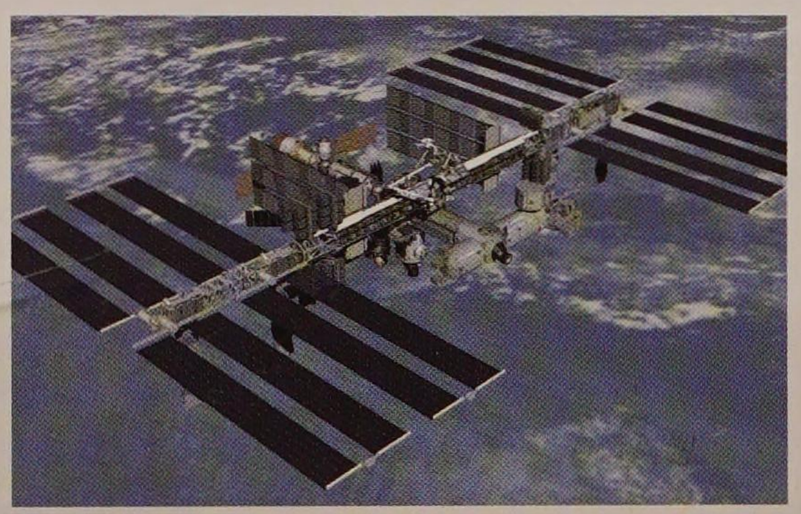
Flags from the ESA countries adorn the rocket boosters

Ariane 5 takes payloads into space

Up-to-date news

Keep right up to the minute on space activities by watching videos on the web.

- For NASA news watch clips on: **www.youtube.com/user/NASAtelevision**
- Opportunity has its own Twitter and Facebook pages: **twitter.com/MarsRovers** and **www.facebook.com/mars.rovers**
- Follow NASA astronaut news on: **twitter.com/NASA_Astronauts**



International Space Station

For information on the International Space Station (ISS), look on the NASA spaceflight site and on the ESA's ISS pages: **spaceflight.nasa.gov/realdata/tracking**

Pancam cameras take panoramic views

Equipment deck protects body underneath

Tools for rock analysis

ADDITIONAL WEBSITES

- Chinese space program: **www.cnsa.gov.cn/n615709/cindex**
- British Space Agency: **www.bis.gov.uk/ukspaceagency**
- Japanese space program: **www.jaxa.jp**
- Russian space news: **www.russianspaceweb.com**
- Space science site for children: **www.nasa.gov/audience/forkids/kidsclub/flash/index.html**

Glossary

Astronaut in space

AIRCRAFT A machine capable of flight, such as an airplane or helicopter.

ALIEN A creature that comes from a world other than Earth.

ANTENNA A device, often in the shape of a rod or dish, used for receiving or transmitting radio waves.

APERTURE The hole or an opening through which light travels; for example, into a telescope.

ASTEROID A small, rocky body orbiting the Sun. Most are in the Main Belt between Mars and Jupiter.

ASTRONAUT A man or woman who travels into space.

ASTRONOMER Someone who studies the stars, planets, and other objects in space.

ATMOSPHERE The layer of gases held around a planet, moon, or star by its gravity.

BAR CODE A machine-readable code in the form of numbers and parallel lines printed on an object.

BIG BANG The explosive event that created the universe 13.7 billion years ago.

BLACK HOLE The remains of a star or a galaxy core that has collapsed in on itself. A galactic black hole is often referred to as a super-massive black hole.

BOOSTER ROCKET A rocket used to provide extra thrust during liftoff of a spacecraft from Earth.

BROADCASTING Transmitting information, or a program, by radio or television.

CAPSULE A small spacecraft or part of a larger one. It usually carries crew or scientific instruments.

CARGO Goods carried on a spacecraft.

COMET A small snow, ice, and dust body. It develops a head and two tails when traveling near the Sun.

CORONA The outermost region of the atmosphere of a star. The Sun's corona can only be seen directly during a total solar eclipse.

COSMONAUT A Russian astronaut, or one from the former Soviet Union.

CRATER A bowl-shaped hollow on the surface of a planet or moon formed when an asteroid crashes into it.

CREW A group of people who operate a spacecraft.

DOCKING When one spacecraft meets another in space and they connect together.

EXTRA VEHICULAR ACTIVITY (EVA) An activity performed by an astronaut outside a spacecraft in space or on the surface of a moon or planet.

Super-massive black hole in the center of the illuminated area

EXTRATERRESTRIAL Something or someone that comes from somewhere other than Earth.

FLYBY A close encounter between a spacecraft and a solar system object.

GALAXY An enormous grouping of stars gas, and dust held together by gravity.

GAS GUN A projectile-firing gun powere by compressed air.

GEOLOGICAL Relating to geology—the study of rocks in order to learn about the history of Earth or another rocky planet, or a moon.

GRAVITY A force of attraction found throughout the universe. The greater the mass of a body, the greater its gravitational pull.

HYDROCARBON A substance that contains only carbon and hydrogen—for example, coal.

HYPERSONIC Relating to speed that is five or more times greater than that of sound.

Lump of coal

INFRARED A form of energ primarily heat energy, th travels in waves longer than light waves.

LANDER A spacecraft that lands on the surfac of a planet, moon, asteroid, or comet.

LAUNCH To send something, such as a rocket, into space and away from the Earth's gravity.

LIFTOFF The upward movement of a rocket as it moves off the ground and starts its journey into space.

LUNAR Relating to the Moon—for example, the lunar surface is the surface of the Moon.

MAGNETIC FIELD Any place where a magnetic force can be measured.

MAGNETOMETER An instrument used for measuring magnetic force

MARTIAN Relating to Mars—for example, the Martian surface is the surface of Mars.

MICROWAVE A form of energy tha travels in waves measuring betwee 0.03 in (1 mm) and 12 in (30 cm).

MILKY WAY The galaxy in which we live It is also the name given to the band of stars that crosses Earth's sky and is our view into the galaxy's disk.

ODULE A complete unit of a spacecraft; r example, Zvezda is a module of the ternational Space Station (ISS).

OON An object made of rock—or ck and ice—that orbits a planet an asteroid.

AVIGATION The process of finding ur position and plotting a route.

BSERVATORY A building or group buildings that house telescopes n Earth. A space observatory is a lescope orbiting Earth.

RBIT The curved path that a natural artificial body follows around another ore massive body.

RBITER A spacecraft that orbits space body, such as a planet an asteroid.

LANET A massive, round body that rbits a star and shines by reflecting e star's light.

ADAR A system to locate an object hereby pulses of radio waves are ansmitted and then reflected back the source.

EMOTE SENSING The obtaining information from a distance—for xample, by an artificial satellite as orbits Earth.

OCKET A propulsion device that as a combustion chamber and an xhaust nozzle. lso the ame for a ehicle that oves way from arth and to the pace, and which arries cargo—uch as a pace probe satellite—or stronauts.

OVER A pacecraft that oves across e surface a planet, steroid, moon.

Ancient telescope

ATELLITE An rtificial object urposely placed in rbit around the Earth or another solar ystem body. Also, another name r a moon or any space object rbiting a larger one.

Planet Earth

SOLAR SYSTEM The Sun and the objects that orbit it, including Earth, seven more planets, and many smaller bodies.

SPACE The place beyond Earth's atmosphere. Also the name for the voids between space bodies, such as the planets, stars, and galaxies.

SPACE AGENCY An organization of one nation or a group of nations that is engaged in space activities—for example, the European Space Agency (ESA).

SPACE PROBE A type of spacecraft, also called a probe. An unmanned robotic craft sent to explore solar system objects.

SPACE SHUTTLE A reusable space vehicle that carries people into space and back to Earth. Also the common name for the US Space Transportation System that operated during 1981–2011.

SPACECRAFT A vehicle that travels in space.

SPACESUIT The all-in-one sealed clothing unit worn by astronauts when outside their craft in space.

SPACE WALK An excursion by an astronaut outside a craft when in space.

TAIKONAUT A Chinese astronaut.

TELECOMMUNICATION Communication over a distance by, for example, telephone or broadcasting.

TELESCOPE An instrument that uses lenses, mirrors—or both—to collect light from a distant object and form that light into an image. Telescopes also collect radio, X-ray, infrared, and ultraviolet energy.

ULTRAVIOLET A form of energy that travels in waves. Ultraviolet waves are emitted by the Sun and can cause sunburn.

UNIVERSE Everything that exists; all space and everything in it.

VAN ALLEN BELT Two doughnut-shaped zones that encircle Earth where high-energy charged particles are trapped by Earth's magnetic field.

WEIGHTLESSNESS The sensation of constantly falling through space that astronauts experience when they are traveling in space.

X-RAY A ray of energy that travels in waves; shorter in wavelength than light waves.

Space shuttle lifting off from launch pad

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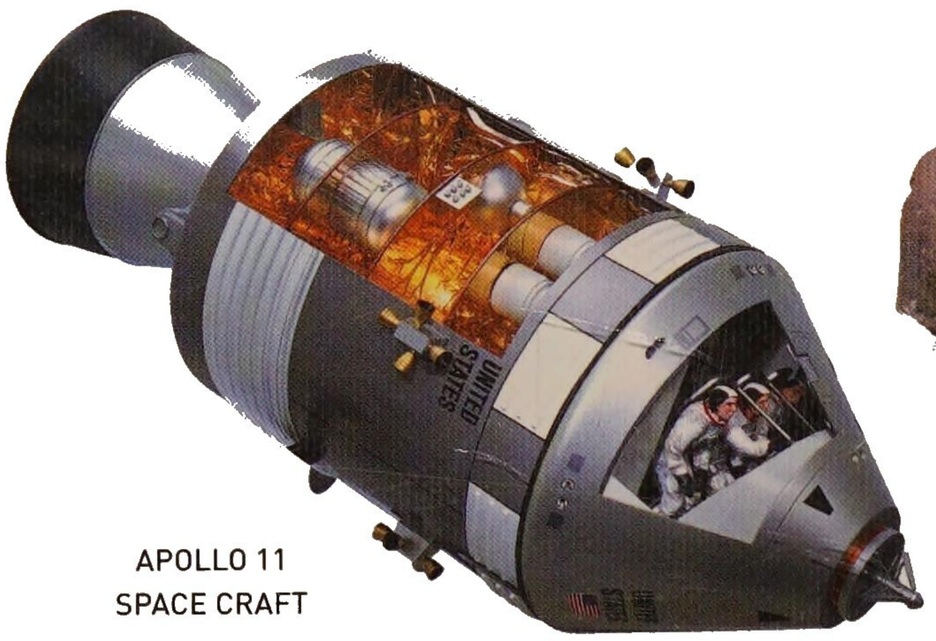

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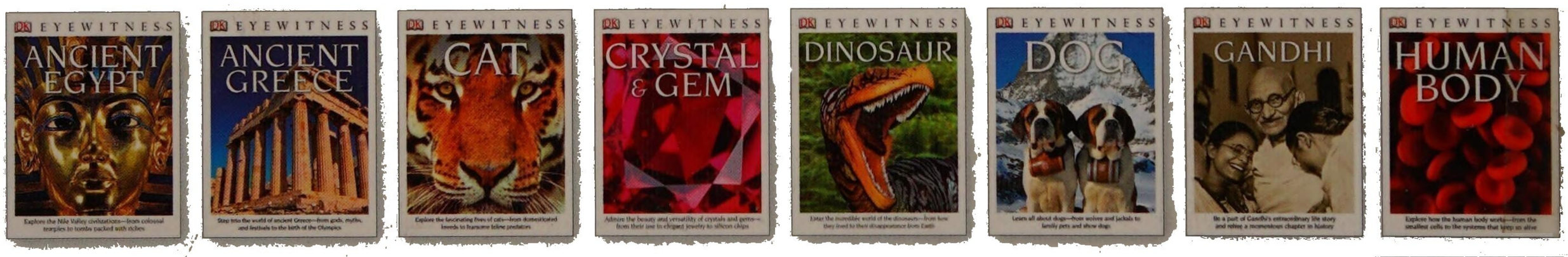

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